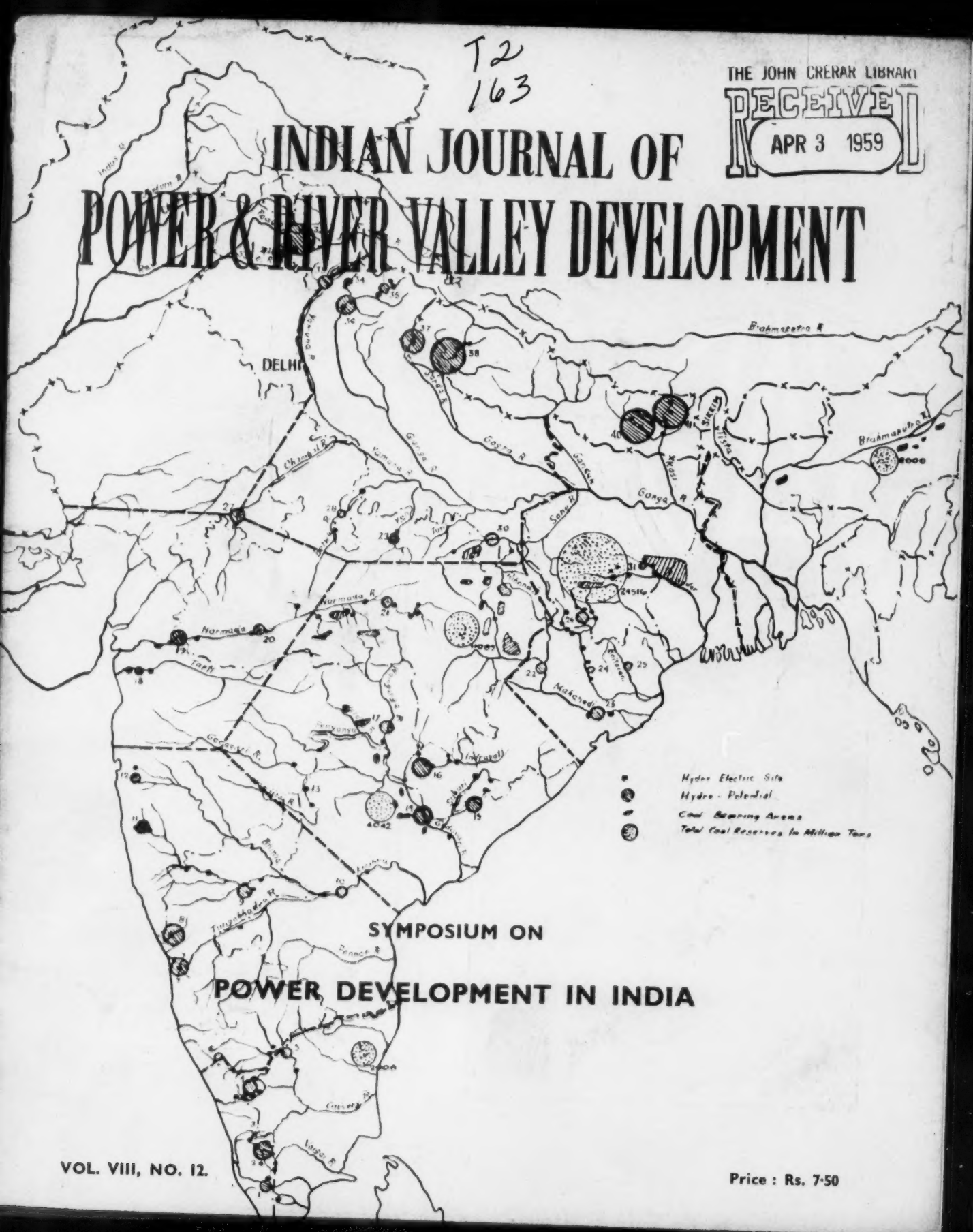
T2
163

THE JOHN CRERAR LIBRARY
RECEIVED
APR 3 1959

INDIAN JOURNAL OF POWER & RIVER VALLEY DEVELOPMENT

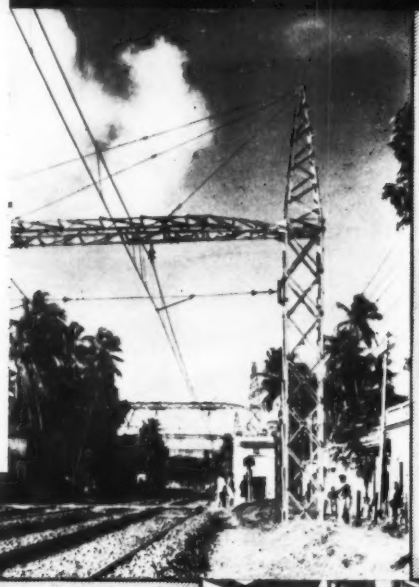


SYMPOSIUM ON

POWER DEVELOPMENT IN INDIA

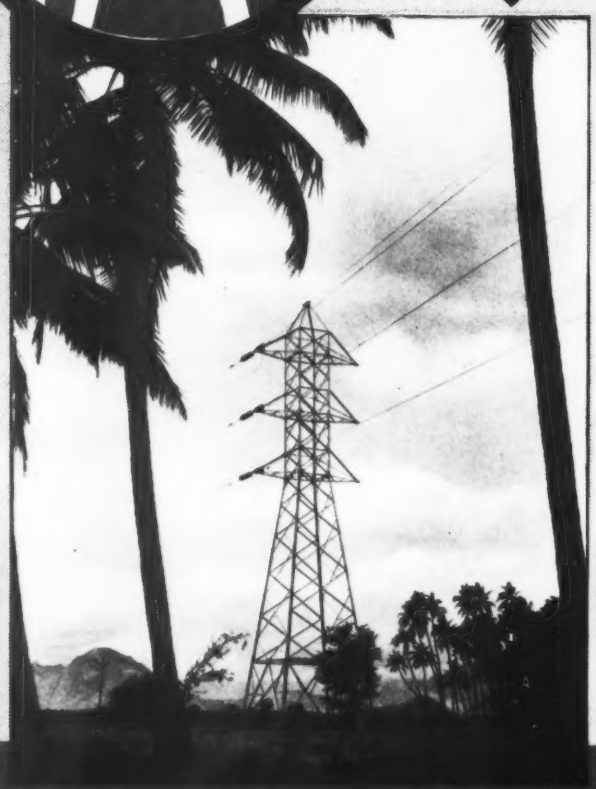
VOL. VIII, NO. 12.

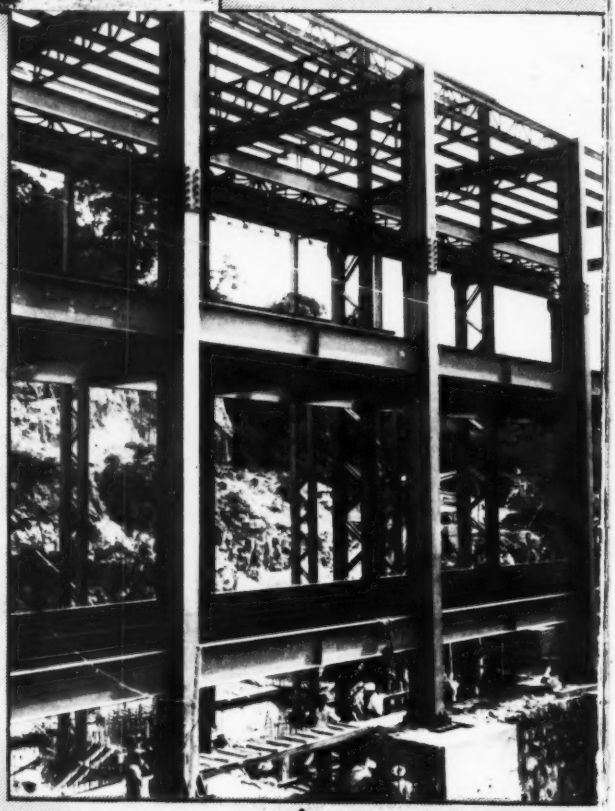
Price : Rs. 7·50



One of the Cantilever type Structures with 3000 D. C. overhead equipment supplied and erected by S. A. E. on the Eastern Railway between Howrah - Burdwan.

A 132 KV D/C Line constructed by S A. E. (Supply and Erection) for the Madras Government.

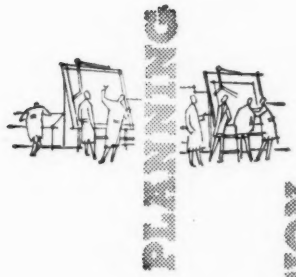




A view of the Periyar Power House under construction by S. A. E. (Supply and Erection)

S. A. E. (INDIA) PRIVATE LTD.

16 A, ST. GEORGE TERRACE, CALCUTTA-22



SIEMENS

Through all the Stages of a Project

from investigation on site to planning, production, installation and subsequent servicing– a staff of highly qualified specialists set their pride in working out optimum solutions to all problems.

Over 170,000 employees enable the House of Siemens, whose name and emblem is known throughout the electrical world, to handle any electrical engineering problem, regardless of scope, complexity or location.

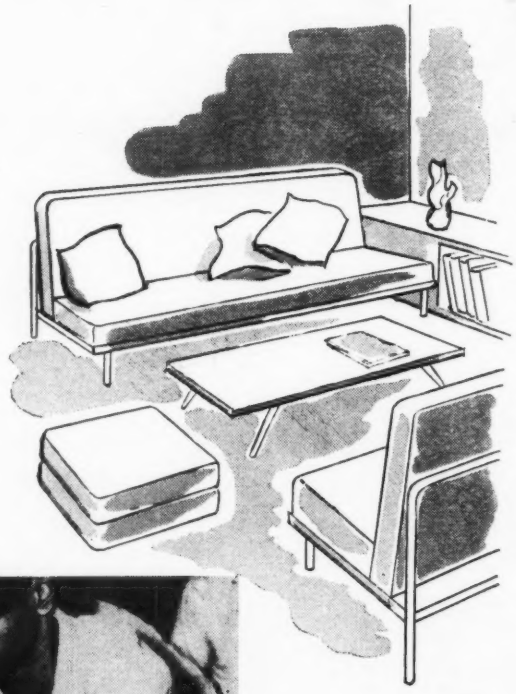
SIEMENS
INDIA

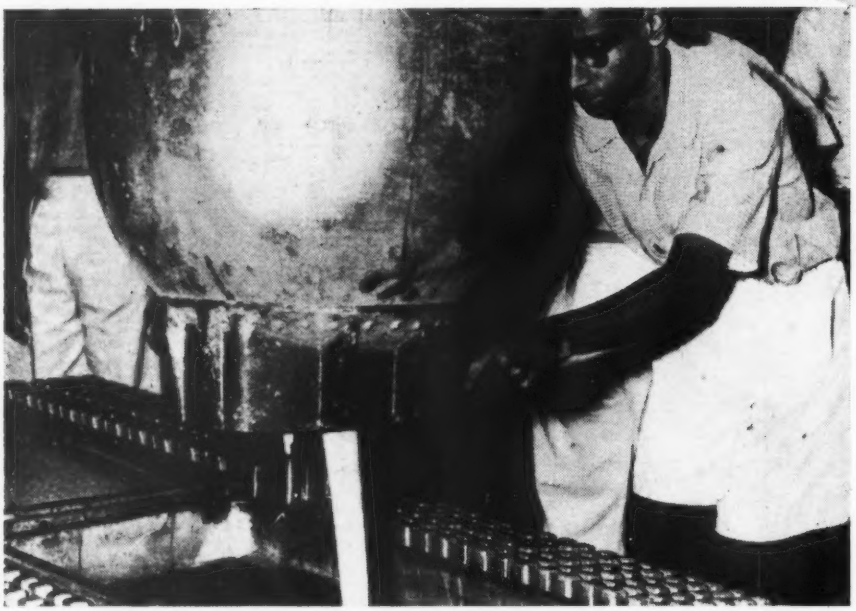
Another emblem, the one shown above, will soon be known throughout the technical world of India. It will be a hallmark of quality for motors, transformers, switchgear, cables and meters soon to be built under Licence in this country in cooperation with noted Indian industrial enterprises.

SIEMENS & HALSKE AG · SIEMENS-SCHUCKERTWERKE AG
BERLIN · MÜNCHEN · ERLANGEN
SOLE REPRESENTATIVES:
SIEMENS ENGINEERING & MANUFACTURING CO. OF INDIA PRIVATE LTD.
BOMBAY · CALCUTTA · NEW DELHI · MADRAS · BANGALORE

Oil...for lasting comfort!

Did you know that oil is partly responsible for the 'built-in' comfort of every Dunlopillo mattress. A special mineral oil with low viscosity characteristics is put into the mixing tank with latex and other ingredients. It is a highly secret formula, so we cannot give you any more details ... the fact remains however that latex foam, as we know it today, would be impossible without oil.





Pouring the foamed latex into the mould where it is cured by steam heat to make the finest mattresses, cushions, seats and other products.

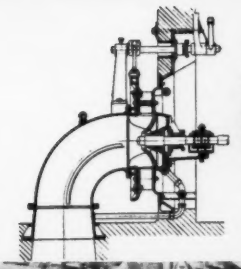
The Dunlop Rubber Company (India) Ltd. is one of the many industrial concerns—large and small—which have come to rely on lubricants and process ingredients bearing the SHELL or B.O.C. name and trade mark.

BURMAH-SHELL
FOR PLANNED LUBRICATION

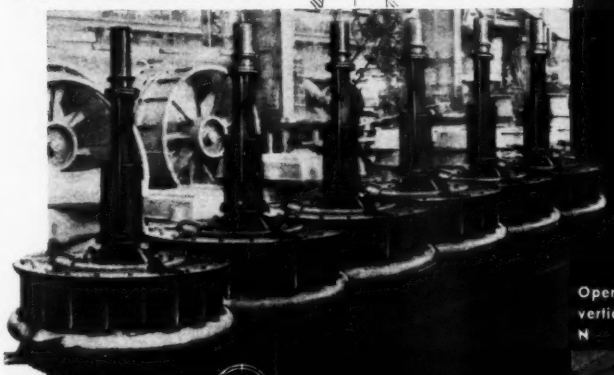
TU 708

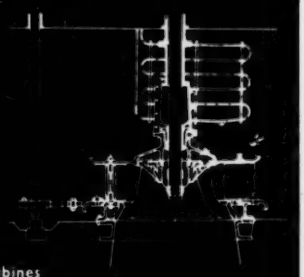
Turbines-series production

Including speed governor and turbine accessories

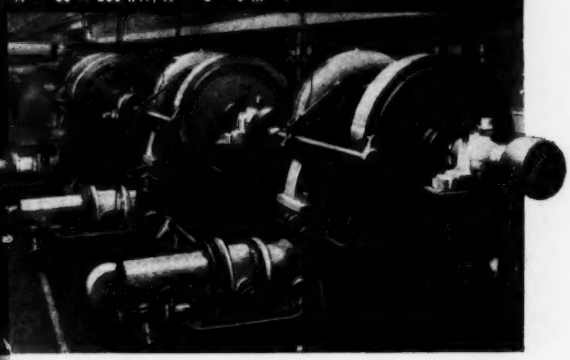


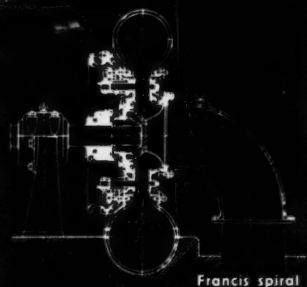
Open flume Francis turbines horizontal shaft, no. V and VI
N = 20 — 100 kW, H = 3 — 6 m



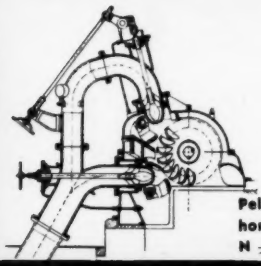


Open flume Francis turbines vertical shaft, no. I — IV
N 60 — 200 kW, H 2 — 5 m





Francis spiral turbines horizontal shaft, no. VII — X
N 80 — 280 kW, H 15 — 60 m



Pelton turbines horizontal shaft, no. XI and XII
N = 80 — 100 kW, H = 40 — 70 m

Our expert engineers are well prepared to consult you nsch! at any time required. Ask for prospectus!

J.M. VOITH
AUSTRIA

St. Poelten, P.O.B. 168 — Telephone 25 01 — Teletype 01 510.
Cable address: Voithwerk St. Poelten.

mt

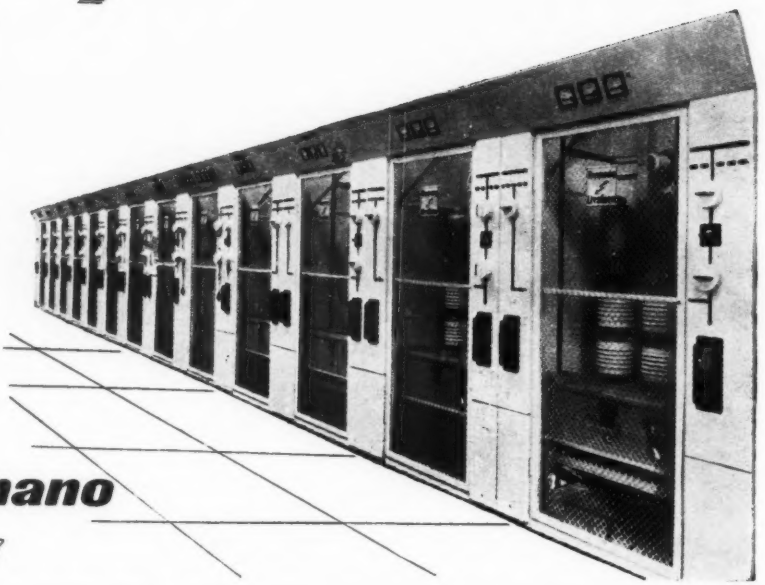
New series

of medium voltage circuit breakers

The right shown circuit breakers, MT/150-P model for 10 kV rated voltage, are part of a supply for Messrs. Peterson & Son, Moss (Norway).

This small oil circuit breakers series for medium voltage — from 10 to 45 kV, 500 MVA — successfully underwent all type tests as stated by I. E. C. Standards, performed at the KEMA Laboratory (Holland), conquering in a couple of years the international market.

Hundreds of MT circuit breakers have been in fact supplied, not only in Italy, but also to Finland, Sweden, New Zealand, Ireland and Turkey, everywhere obtaining a bright success.



Scarpa & Magnano

VIA FIUME 2 - SAVONA - ITALY

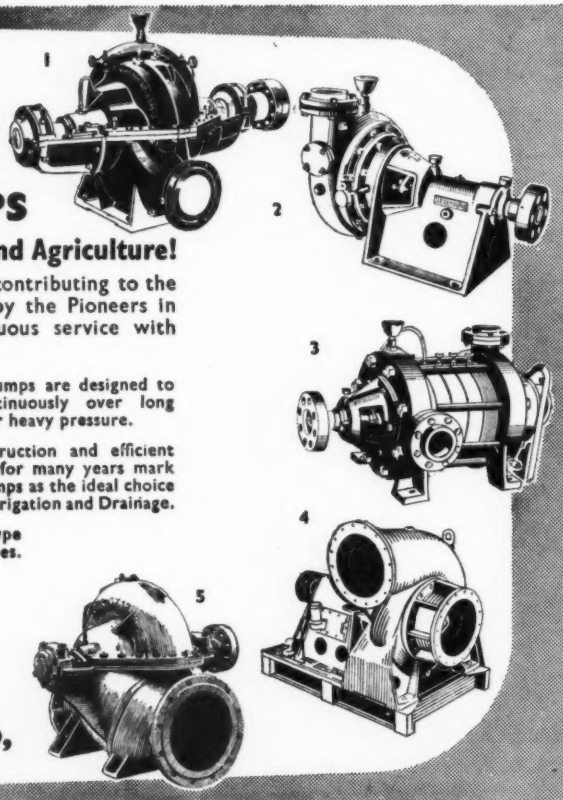
THE 'BIG FIVE'

CENTRIFUGAL PUMPS

are Partners in the Progress of Industry and Agriculture!

Here are the Pumps of proven value that have been contributing to the growth of Industry and Agriculture. Manufactured by the Pioneers in the field, you can be assured of years of continuous service with minimum maintenance cost.

1. Type 'DSM' Pumps are suitable for handling low quantities of water against high heads.
2. 'NK' type Pumps are designed to operate continuously over long periods under heavy pressure.
3. 'Multistage' Pumps are in effect a combination of two or more pumps within a single casing—for installation where the head is high.
4. Sturdy construction and efficient performance for many years mark 'MF' type Pumps as the ideal choice of Industry, Irrigation and Drainage.
5. Defined as the 'general purpose' Pumps, type 'UP' are adaptable to a wide range of duties.



Kirloskar

ESTD. 1888

KIRLOSKAR BROTHERS LIMITED,

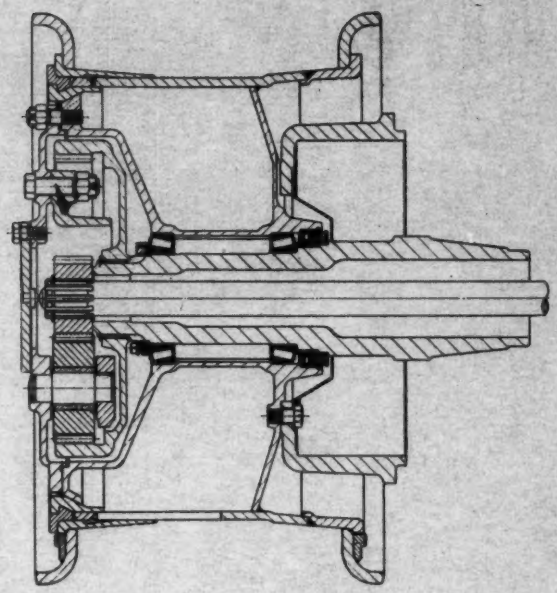
KIRLOSKARVADI, DIST. S. SATARA

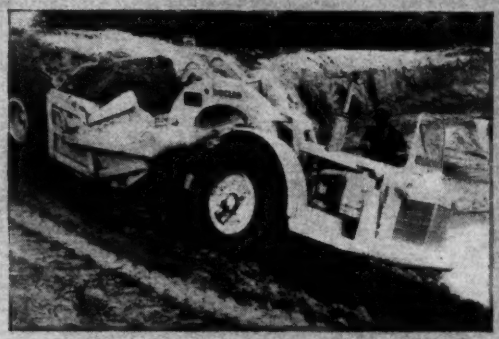
Q. 61

TIMKEN Made in U.S.A.

TRADE-MARK ORIGINATED, OWNED, REGISTERED BY THE TIMKEN ROLLER BEARING COMPANY

TAPERED ROLLER BEARINGS





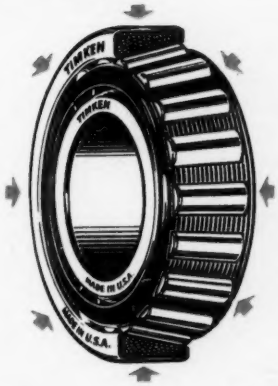
Scraper drive wheels, (like at left) as well as differential, pinion and trail wheels are mounted on Timken made-in-U.S.A. tapered roller bearings.

Scraper takes turns, twists and bumps with Timken Bearings to roll the loads

Working over rough terrain this scraper takes a beating. To keep it working engineers specified Timken made-in-U.S.A. tapered roller bearings for the wheels, differential and pinion.

Timken bearings are specified for this rough, tough use because: 1) *They have greater capacity.* Full line contact between rollers and races gives Timken bearings *extra* load carrying capacity. And because they're tapered, they take any combination of radial and thrust loads (as shown at right). 2) *They take shock.* Timken bearings are made of our own special analysis steel. And they are case-carburized to have hard, wear-resistant surfaces and tough, shock-resistant cores. 3) *They need less maintenance.* Because they keep shafts concentric with housings, Timken bearings make closures more effective.

To get all the advantages of Timken made-in-U.S.A. bearings, specify them for the machines you buy or build. Made by the world's oldest (59 years) and largest manufacturer of tapered roller bearings. *Available World-Wide.* The Timken Roller Bearing Company, Canton, Ohio, U.S.A.
Cable: "TIMROSCO".

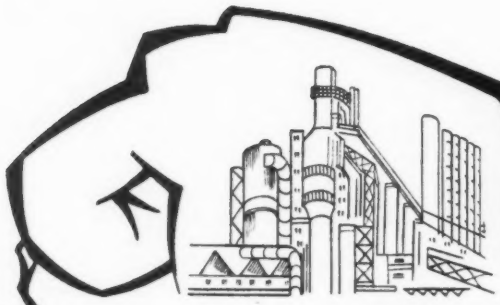


NOT JUST A BALL ◯ NOT JUST A ROLLER ▭ THE TIMKEN TAPERED ROLLER ▭ BEARING TAKES RADIAL ◐ AND THRUST ◔ LOADS OR ANY COMBINATION ◑

TIMKEN U. S. A. BEARING SERVICE

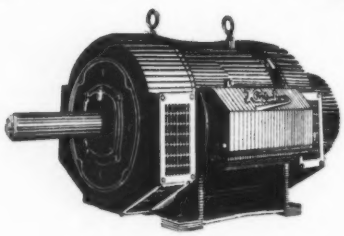
Distributors: **Voltas Limited.** Bombay • Calcutta • Madras • New Delhi • Bangalore • Cochin.

7-800



POWER
YOU CAN
DEPEND ON

Power for industry, power for the ever-growing needs of India, for steel, for agriculture, for textile mills. POWER YOU CAN DEPEND ON. In the field of electric motors KIRLOSKAR are playing their part. KIRLOSKAR electric motors incorporate all the latest designs of the Brush Electrical Engineering Co. and are subject to rigid inspection to ensure dependable power and trouble-free service. Every Brush-Kirloskar Electric Motor has a guarantee of reliability and strength.

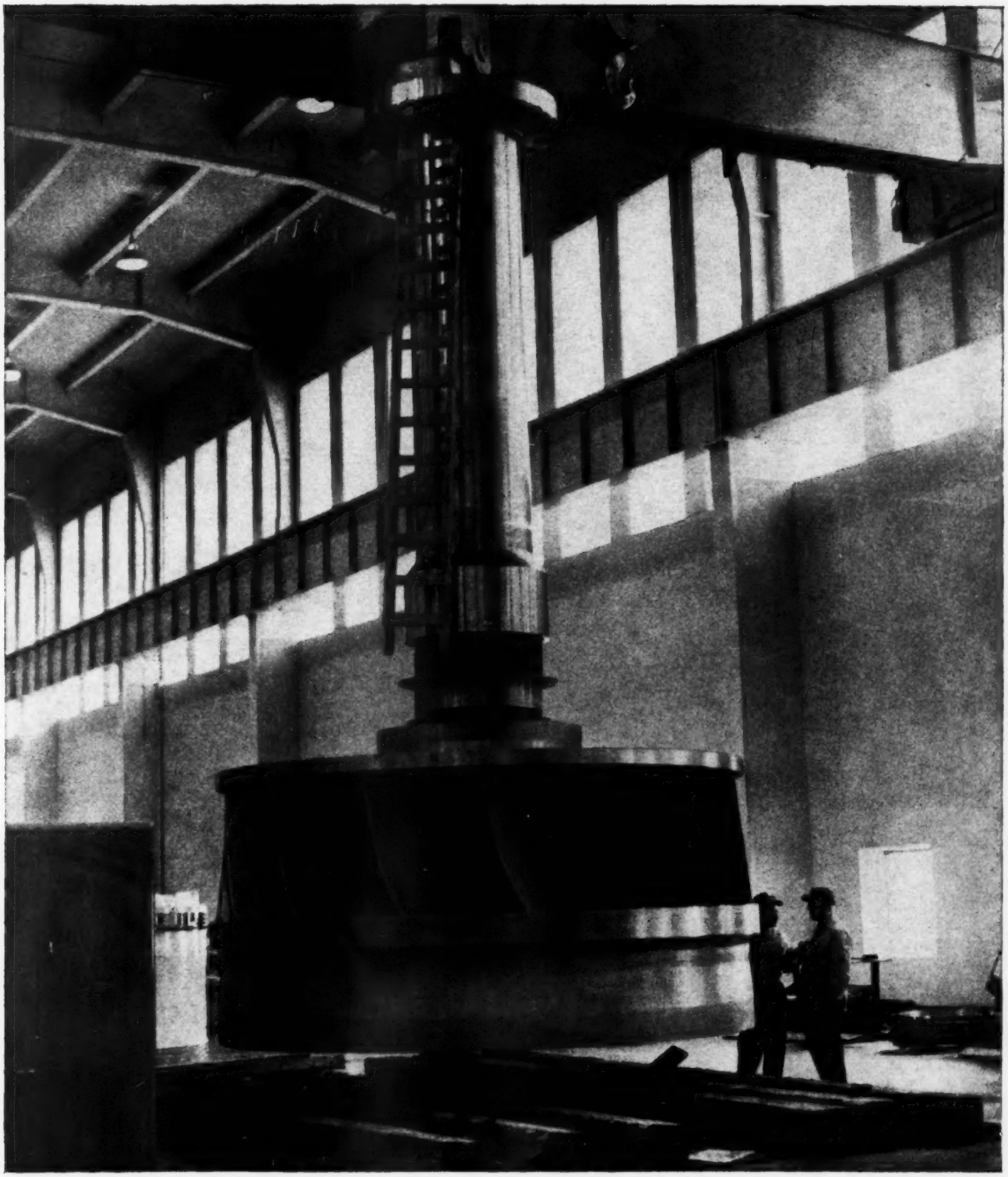


MOTORS UPTO 200 H.P.

6 PK.M-26

Manufactured by
KIRLOSKAR ELECTRIC CO., LTD.
BANGALORE-3

Sole Agents
PARRY & CO. LIMITED
MADRAS
BOMBAY
CALCUTTA
NEW DELHI



SIXTEEN 105,000 HP DOMINION FRANCIS TURBINES INSTALLED AT SIR ADAM BECK-NIAGARA GENERATING STATION No. 2 FOR THE HYDRO-ELECTRIC POWER COMMISSION OF ONTARIO

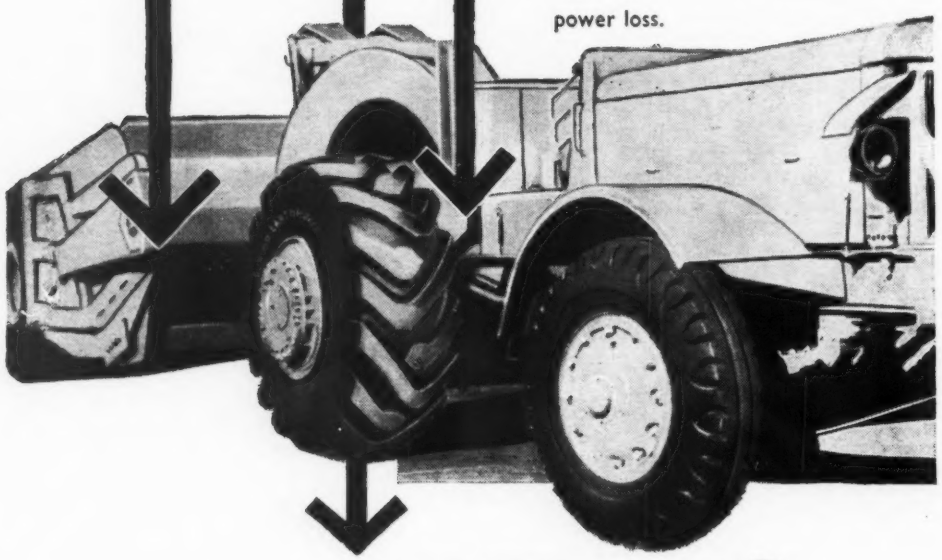
DOMINION ENGINEERING COMPANY LIMITED
P.O. BOX 220, MONTREAL, CANADA, CABLE: DOMWORKS

REPRESENTED IN INDIA BY
THE CROMPTON ENGINEERING CO. (MADRAS) PRIVATE LTD.,
P.O. BOX 205, MADRAS, INDIA

For Rugged
Off-the-road Operations
Dunlop Offer—

NEW PATTERN EARTHMOVER TYRE

The massive tread bars
are of special design,
reinforced to withstand the
most arduous service conditions.
Operators keep ahead of schedule
with this tyre—it gives
maximum traction with minimum
power loss.



Made in India by **DUNLOP**

Available in sizes : 18.00-24 18.00-25
21.00-24 21.00-25

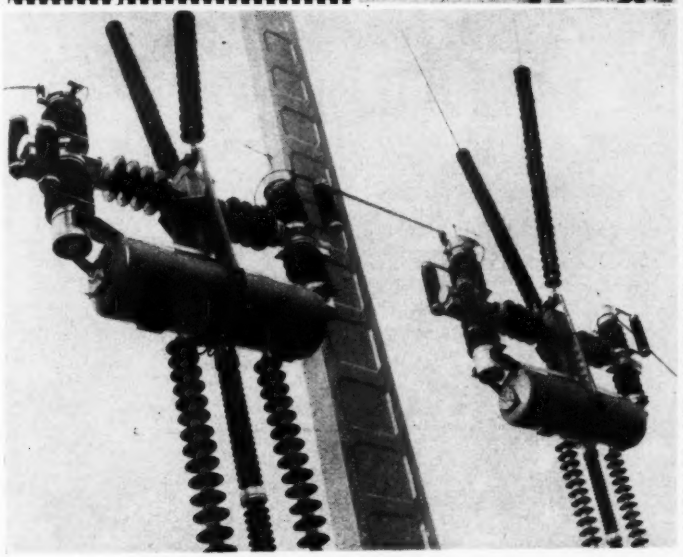
The Dunlop Rubber Co. (India) Ltd.

DTC-13A

high performance

SEMI-PANTOGRAPH DISCONNECTING - SWITCH

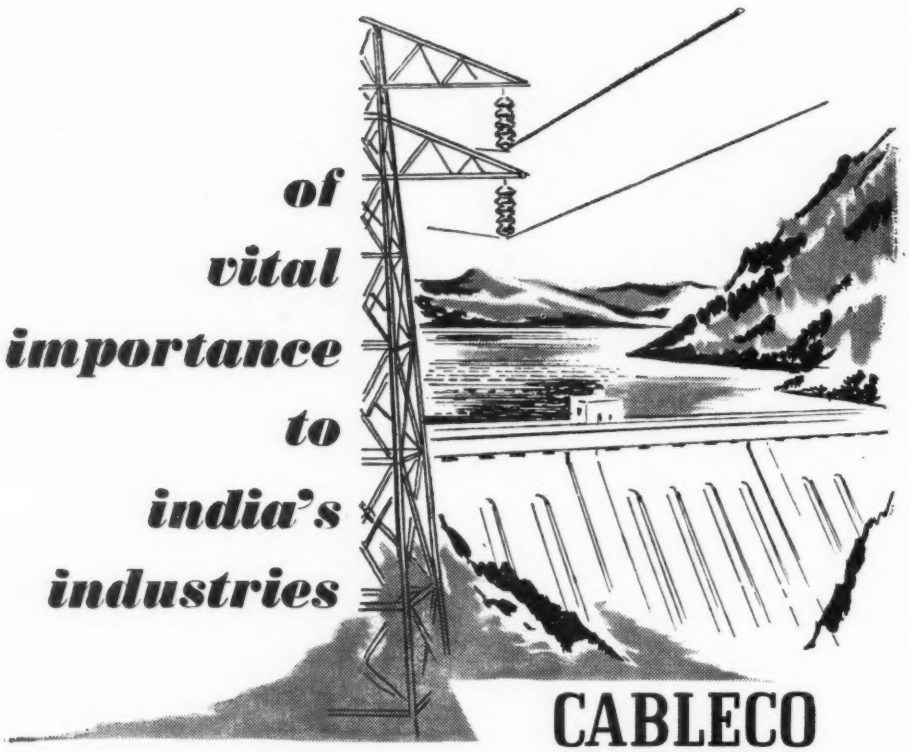
AIR BLAST CIRCUIT BREAKER



420 kv

MERLIN & GERIN

Grenoble - FRANCE



of vital importance to india's industries

CABLECO
Copper A. C. S. R. and Aluminium Conductors

PARAMITE
Cables

PARAMEX
Synthetic Enamel Covered Winding Wires

MANUFACTURED IN INDIA TO IS : 282, IS : 396, IS : 398 & IS : 434. BY

THE INDIAN CABLE CO., LTD

9, HARE STREET, P. O. BOX 514, CALCUTTA

Representatives in India for

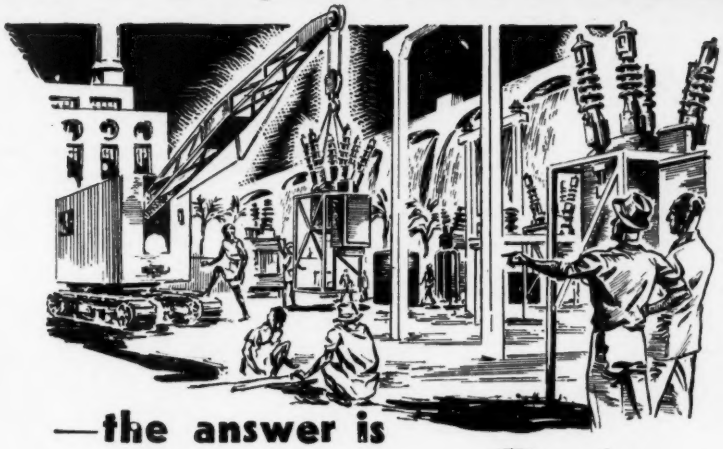
BRITISH INSULATED CALLENDER'S CABLES LTD.

BRANCHES :

AHMEDABAD, BANGALORE, BOMBAY, COIMBATORE, JAMSHEDPUR, KANPUR, MADRAS, NAGPUR, NEW DELHI AND SECUNDERABAD

I.C.15

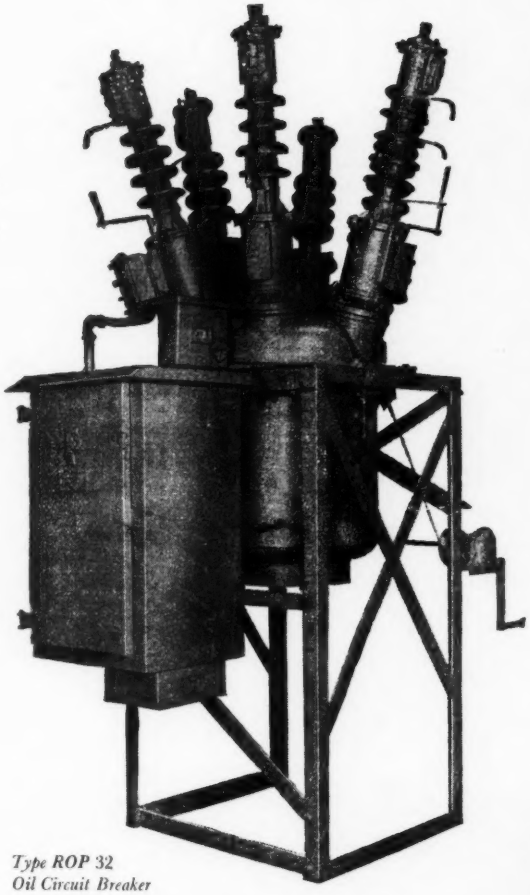
When the call is for SWITCHGEAR—



—the answer is *Ferguson Pailin*

When the dam is built and the major constructional work completed the task of installing the electrical plant and the equipment must be undertaken.

Ferguson Pailin have supplied switchgear for indoor and outdoor stations, including major hydro-electric schemes the world over. 'F. P.' is synonymous with first-class design, manufacture and performance of this essential equipment, ranging from extra high voltage switchgear for main grid supply systems down to low voltage switchgear for industrial purposes.



Type ROP 32
Oil Circuit Breaker

Two examples of 'Ferguson Pailin' switchgear, for varying duties, are illustrated here. They are :—

ROP 32 OIL CIRCUIT-BREAKER

Wherever 22 kV or 33 kV outdoor oil circuit-breakers for breaking capacities up to 750 MVA are required the merits of the 'ROP 32' breaker should be considered.

The design of this breaker provides for the optimum protection against adverse working conditions peculiar to countries in various parts of the world as well as maximum resistance to the effects of fluctuating temperatures and humidity.

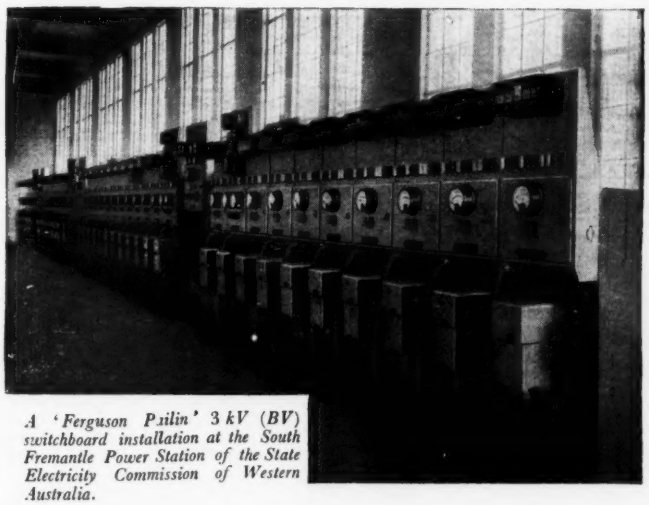
The versatility of the 'ROP 32' makes it remarkably adaptable to local requirements. Complete dependability and reliability make it a natural choice for incorporation into any scheme involving the transmission of power at 22 kV or 33 kV.

The circuit-breaker tank is of cylindrical shape and all three phases are brought into one tank, permitting the use of smaller framework thereby achieving compactness.

'BV' SWITCHGEAR

'Ferguson Pailin' Type BV switchgear is of the completely enclosed metalclad type. It is constructed on the unit principle and can readily be extended by units of similar rating, or by metalclad oil switches.

Vertical isolation of the breaker ensures minimum space requirements of the unit, whilst adequate interlocks safeguard against mal-operation.



A 'Ferguson Pailin' 3 kV (BV) switchboard installation at the South Fremantle Power Station of the State Electricity Commission of Western Australia.

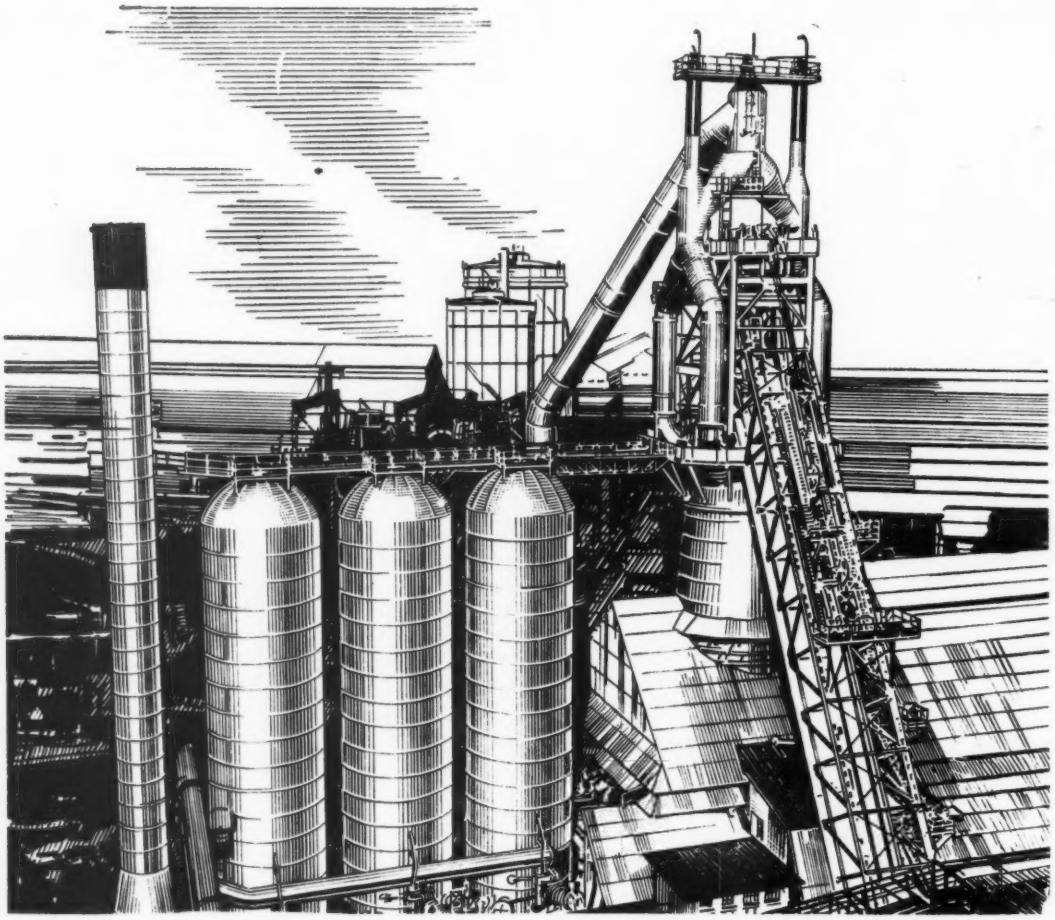
Ferguson Pailin LIMITED — *for Switchgear*

Member of the A.E.I. Group of Companies

Head Office & Works: **HR. OPENSHAW MANCHESTER 11. ENGLAND**

Represented in India and Pakistan by

A. E. I. (India) Private Ltd., Head Office : Crown House, 6, Mission Row, Calcutta, P. O. Box 271.
A. E. I. (Pakistan) Ltd., Head Office : Bombay Company Building, Wallace Road, Karachi, P. O. Box 746.



An iron for every casting

IISCO STANDARD FOUNDRY MACHINE CAST PIG IRON

The basic requirement for the production of any good casting is the supply of controlled quality pig iron. The Indian Iron & Steel Company Limited, in order to ensure consistent quality of the various grades of pig iron manufactured, maintain a well-equipped laboratory where qualified personnel conduct sample analyses throughout the 24-hour production period. Available in 40/45 lbs. single notch pigs, IISCO Standard Foundry Machine Cast Pig Iron comes in many grades to give you an iron for all types of castings.

THE INDIAN IRON & STEEL COMPANY LIMITED

IISCO

WORKS: BURNPUR & KULTI

Managing Agents: MARTIN BURN LIMITED

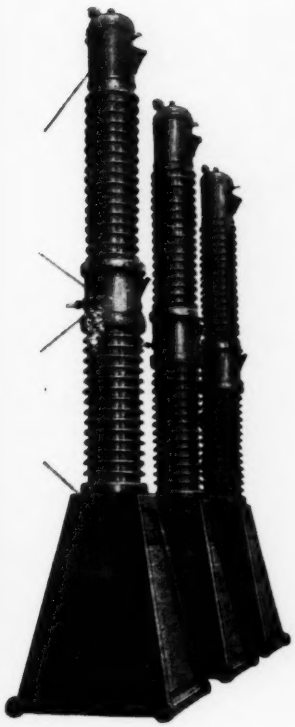
12, Mission Row, Calcutta 1.

Branches: New Delhi, Bombay, Kanpur

IIC 69

The work MAGRINI has realized during more than half a century is clearly evidenced by its supplies in all countries of the world

Electrich Switchgear
for low, medium and high voltages
up tho 380 kV
Standardized Metal Clad Switchboards
with draw-out equipment
Electrical Equipment for Railways
and for use on Vessels



EASUN ENGINEERING COMPANY - P. O. BOX 95 - MADRAS

MAGRINI s. p. a.
BERGAMO (ITALY)
Via Magrini, 7 - Phone 35.444

28 YEARS of maintenance-free concrete road service!

The Dum Dum—Jessore Road, Calcutta

The ever-growing traffic in India needs concrete roads, because:

Concrete Roads

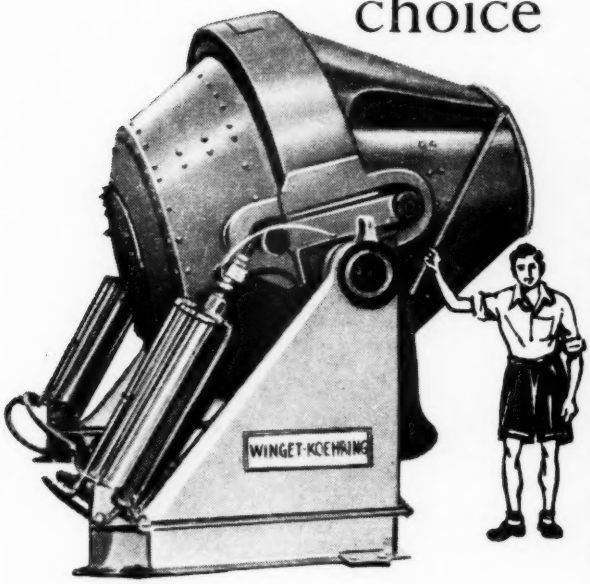
- Cost less to build than any other road of equal load-carrying capacity
- Cost less to maintain
- Give long years of service
- Give better visibility
- Help to avoid accidents

ACC CEMENT
—a product of Free Enterprise

Build to last with *ACC* Cement—plenty available now at controlled price

THE ASSOCIATED CEMENT COMPANIES LIMITED • The Cement Marketing Company of India Private Ltd.

The expert's choice



Hirakud Dam
Vaitarna Dam
Bokaro Thermal Station
Rihand Dam
Bhakra Dam
Maithon Dam
Tilayia Dam Power House
Durgapur Barrage
Kosi Project
Koyna Dam
Indian Air Force

WINGET-KOEHRING CONCENTRIC ZONE MIXERS
THE CONCRETE MIXER WITH THE PNEUMATIC TILT

1, 2, 3 and 4 cubic yard capacities

Ask Jacks about it

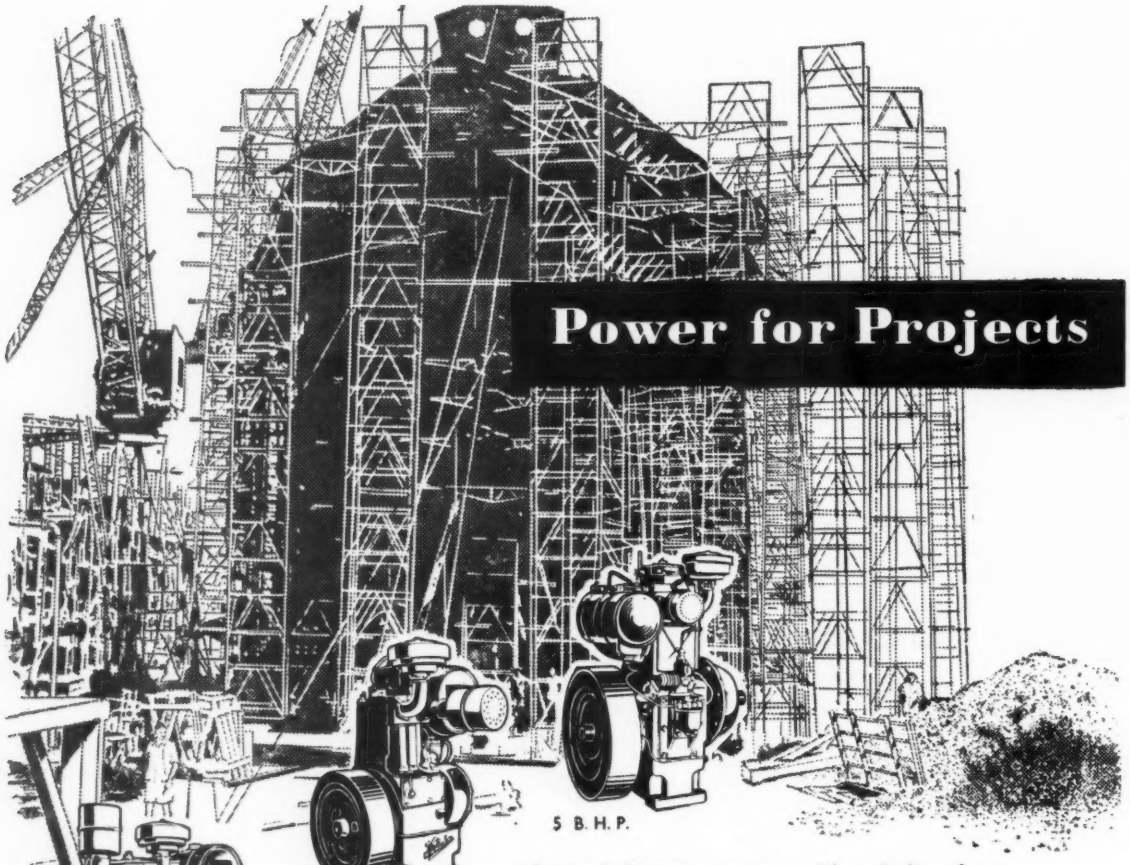
William Jacks & Co. Ltd.

(Incorporated in England. Liability of Members Limited.)

CALCUTTA BOMBAY MADRAS

Portable Models from 3/2 cu. ft. to 21/14 cu. ft. Always in Stock

WJC-283



Power for Projects

5 B. H. P.

10 B. H. P.

20 B. H. P.

40 B. H. P.

National Projects promise New India of prosperity. Throbbing with energy, famous KIRLOSKAR DIESEL ENGINES power these projects, speeding construction of dam and powerhouse, road and bridge.....With scores of applications in agriculture and industry, easy to maintain, reliable in service, economical to operate, Kirloskar Engines are the power units for resurgent India.

Kirloskar

AGRICULTURAL
INDUSTRIAL and MARINE
DIESEL ENGINES

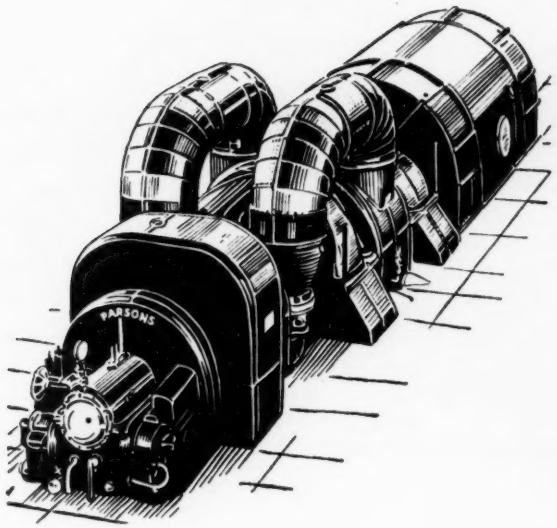
KIRLOSKAR OIL ENGINES LTD., KIRKEE, POONA 3 (INDIA)

KOEL/E-12/58

TOM & BAY

C. A. PARSONS

100
120
200
300
and now



550 M.W. *STEAM TURBO-GENERATORS*

Machines of the sizes above and smaller ratings are under construction at the Heaton Works of C. A. Parsons & Co. Ltd.

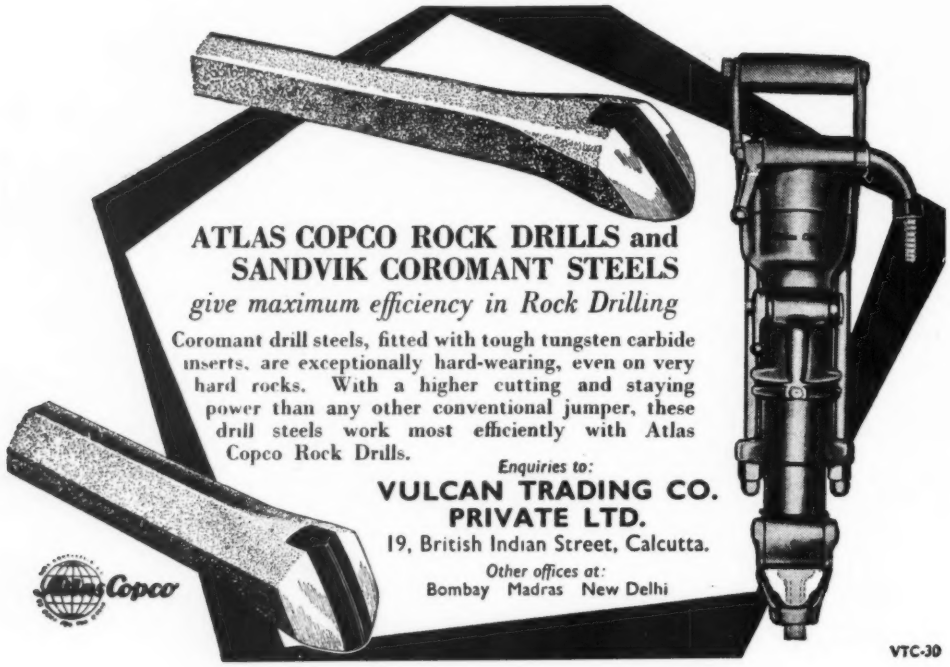
The 550 M.W. set, which is to be installed at the new THORPE MARSH generating station of the Central Electricity Generating Board, will be the largest Steam Turbo-Generator in the world.

Agents in India

MARTIN BURN LTD.

Calcutta New Delhi Bombay Kanpur

MPCC-8



ATLAS COPCO ROCK DRILLS and SANDVIK COROMANT STEELS

give maximum efficiency in Rock Drilling

Coromant drill steels, fitted with tough tungsten carbide inserts, are exceptionally hard-wearing, even on very hard rocks. With a higher cutting and staying power than any other conventional jumper, these drill steels work most efficiently with Atlas Copco Rock Drills.

Enquiries to:

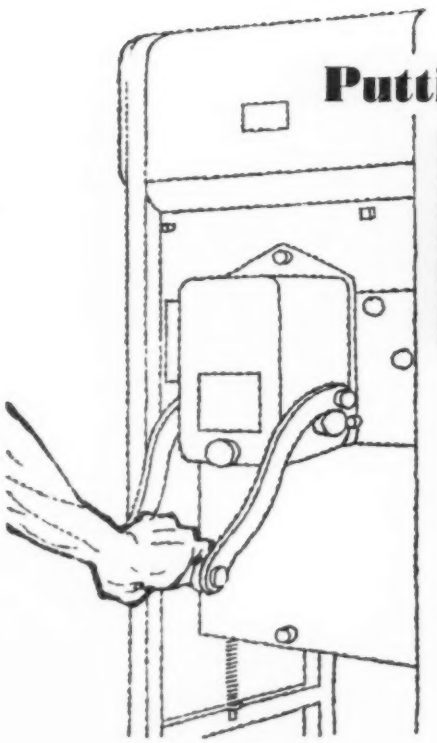
VULCAN TRADING CO. PRIVATE LTD.

19, British Indian Street, Calcutta.

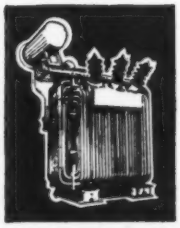
Other offices at:

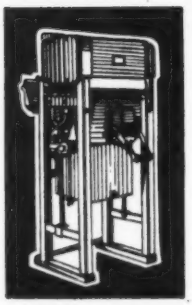
Bombay Madras New Delhi

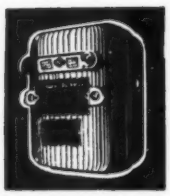
VTC-30

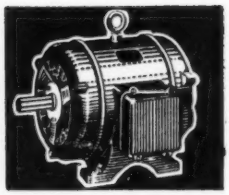


Putting electricity to work







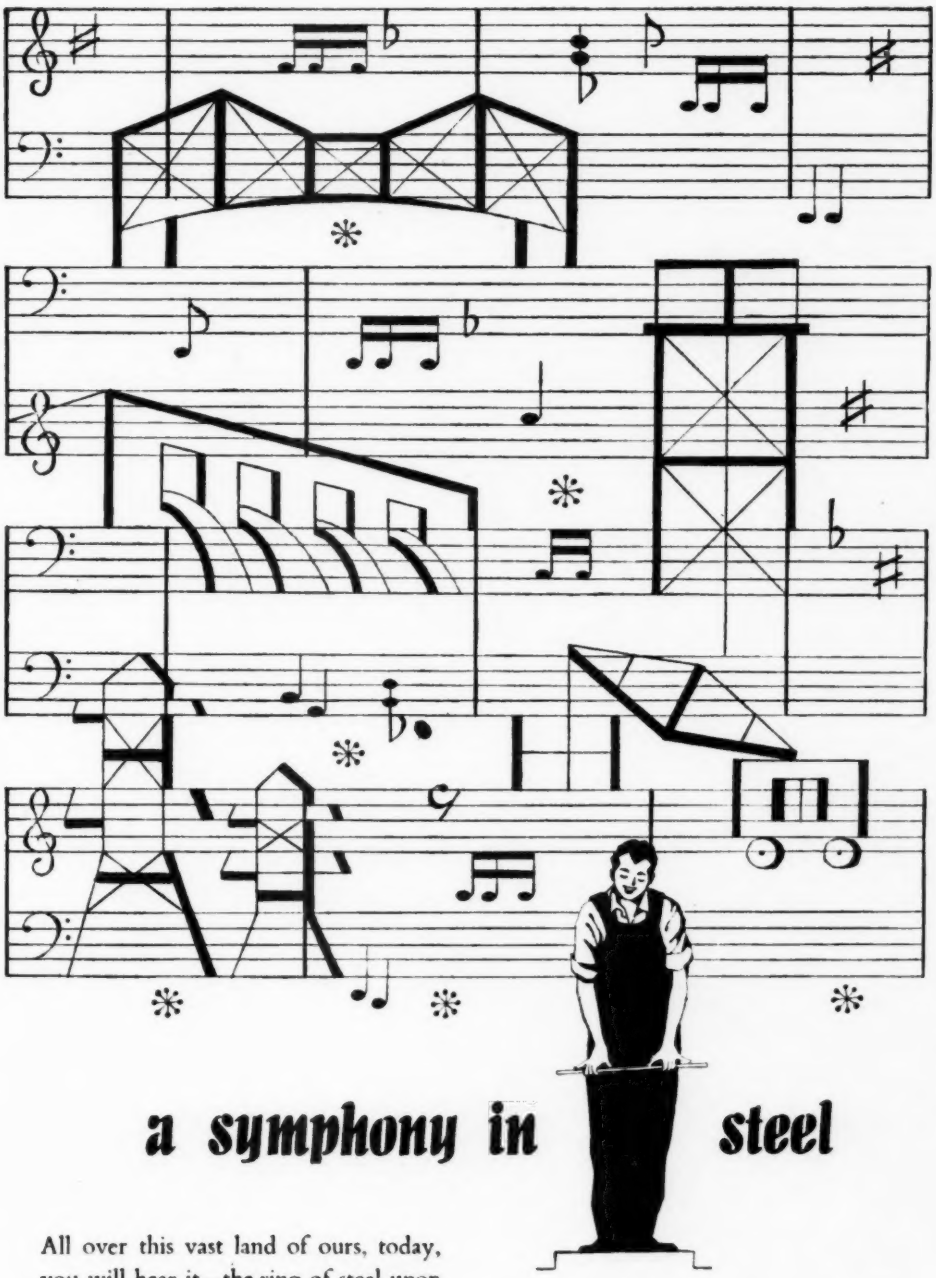


We can supply all the electrical equipment required for use with electricity supplies becoming available under the Second Five Year Plan.

GREAVES COTTON & CROMPTON PARKINSON PRIVATE LIMITED.

Post Box No. 91, Bombay 1
Post Box No. 166, Calcutta 1
Post Box No. 197, New Delhi 1

CP 32



a symphony in steel

All over this vast land of ours, today, you will hear it—the ring of steel upon steel as a mighty nation surges ahead in its quest for industrial prosperity. It is a symphony of stupendous magnitude and Texmaco plays an important part in it. Here at Belgharia, work the Texmaco men and machines, manufacturing steel bridges for spanning the mighty rivers; steel transmission towers for carrying electric power; steel cranes for moving materials, speeding production; steel equipment for hydro-electric and irrigation projects— men and machines working in unison, playing the symphony in steel.

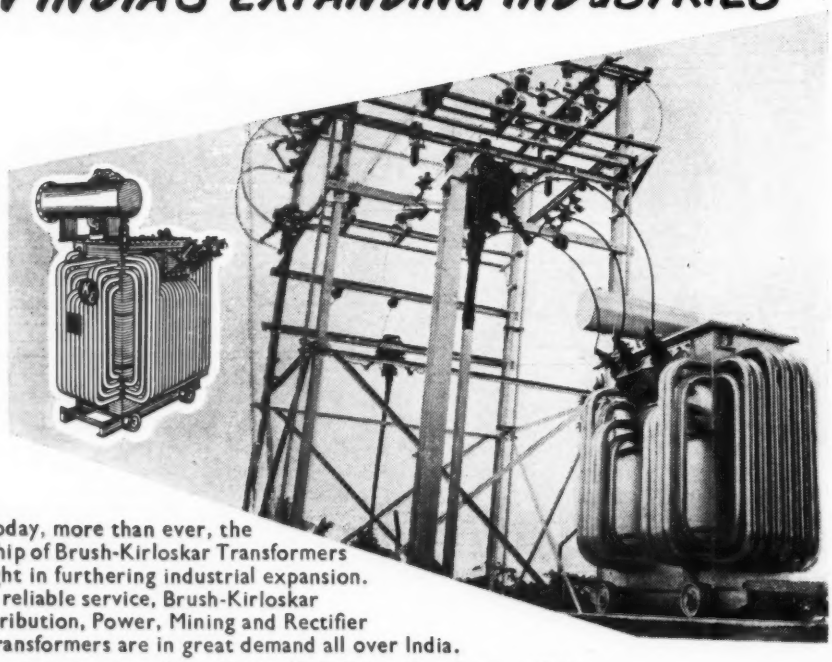
TEXMACO *serves India's basic industries*

TXC-45

TRANSFORMERS...

POWERFUL PARTNERS

IN INDIA'S EXPANDING INDUSTRIES



Today, more than ever, the partnership of Brush-Kirloskar Transformers is sought in furthering industrial expansion. Built for reliable service, Brush-Kirloskar Distribution, Power, Mining and Rectifier Transformers are in great demand all over India.

Range: Transformers - from 15 to 3000 kVA, 33 kV, are available from the manufacturers or the selling agents

MANUFACTURED BY:
KIRLOSKAR
ELECTRIC CO. LTD.
BANGALORE-3

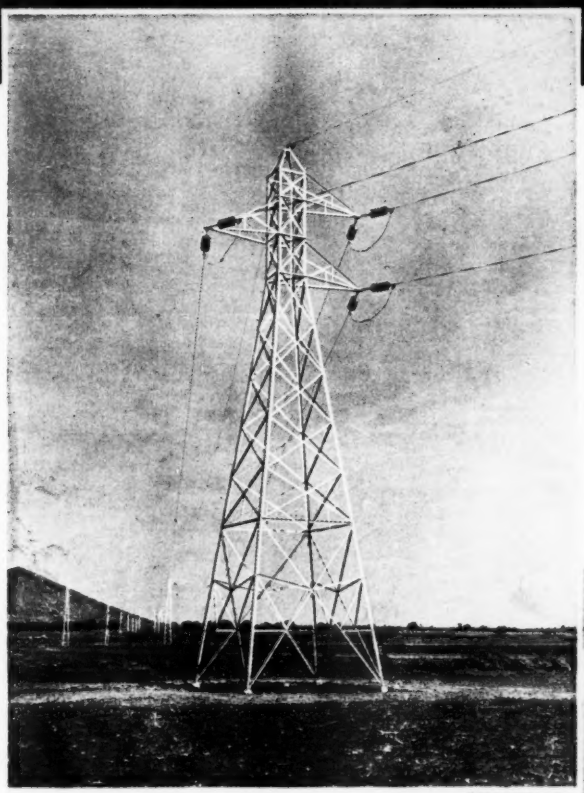
SOLE AGENTS:
PARRY & CO. LIMITED
MADRAS
BOMBAY
CALCUTTA
NEW DELHI

Keymers PTZ-4

TRANSMISSION TOWERS

DESIGNED TO CARRY ANY LOAD

TO FIT ANY TERRAIN

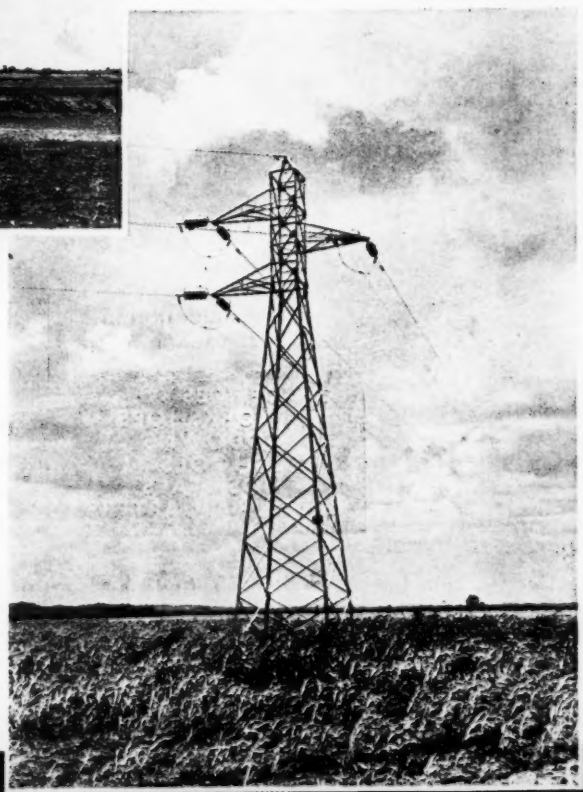


CROMPTONS' STEEL TOWERS CARRY MANY HUNDREDS OF CIRCUIT MILES OF TRANSMISSION LINES ACROSS THIS GREAT LAND. SCALING THE HEIGHTS OF RUGGED MOUNTAINS. THROUGH MARSHY LOW LANDS. TRAVERSING EVERY POSSIBLE KIND OF TERRAIN, THESE TRANSMISSION TOWERS ARE SIGNPOSTS OF INDIA'S PROGRESS.

CROMPTONS HAVE BEEN DESIGNING. FABRICATING AND ERECTING TRANSMISSION LINE TOWERS FOR THE NATION FOR OVER 25 YEARS. THEIR EXPERIENCE AND FACILITIES ARE SECOND TO NONE.

TRANSMISSION LINES ERECTED

MADRAS :	66 KV.	..	168 miles
	110 KV.	..	256 miles
ANDHRA PRADESH :	33 KV.	..	50 miles
	66 KV.	..	295 miles
	132 KV.	..	116 miles
KERALA :	66 KV.	..	92 miles
	110 KV.	..	125 miles
BURMA :	33/66 KV.	..	500 miles



Consult:

THE CROMPTON ENGINEERING CO. (MADRAS) PRIVATE LTD.

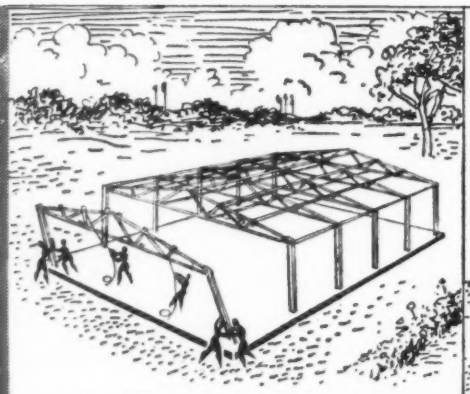
POST BOX No. 205, SECOND LINE BEACH, MADRAS-1

Branches BOMBAY, NEW DELHI, BANGALORE, COIMBATORE, MADURAI, VIJAYAWADA & SECUNDERABAD

S&L

STANDARD
LIGHT STRUCTURES
FOR PERMANENT & TEMPORARY BUILDINGS

New constructional principle effects amazing time saving

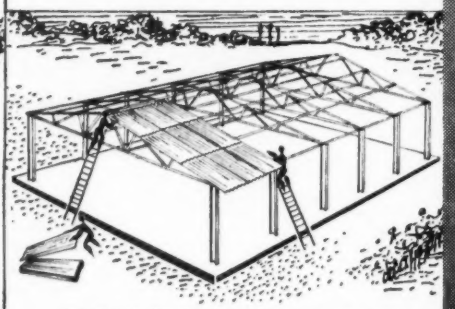


ROOF TRUSSES AND PURLINS OF TUBULAR CONSTRUCTIONS IN THREE STANDARD SPANS

SPAN	TRUSS SPACING
44′	13′ 4″
30′	13′ 4″ OR 10′ 0″
20′	10′ 0″

COLUMN AVAILABLE IN FOUR STANDARD HEIGHTS
9′ 6″, 12′ 0″, 14′ 0″ AND 16′ 0″

Six unskilled men take approximately sixteen hours to erect on prepared foundation steelwork for a building over 60′ long by 30′ wide



Roofing is fixed before the work on walls and interior is begun

EXTENSIVELY USED BY
ALL THE STEEL PROJECTS
RAILWAYS
CONSTRUCTION SITES
INDUSTRIAL ORGANISATIONS

FOR OFFICES
WORKSHOPS
GODOWNS
SCHOOLS
HOSPITALS
LABOUR QUARTERS

PROMPT DELIVERIES

Write for particulars & price lists to

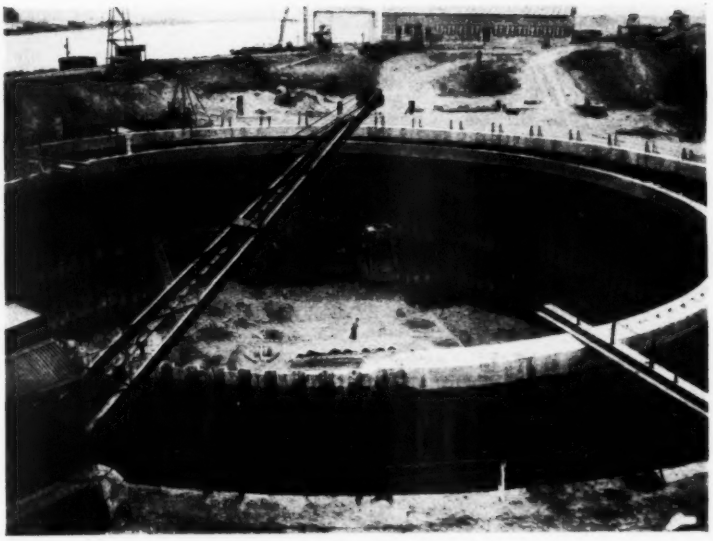
STEWARTS AND LLOYDS OF INDIA PRIVATE LTD.

TELEPHONE 44-5224 (7 LINES) and 44 1451
TELEGRAMS : TUBEMAKERS, CALCUTTA

41, CHOWRINGHEE, CALCUTTA-16

SLF-2-58

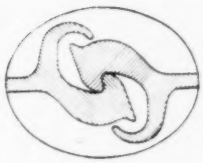
STEEL SHEET PILING ARBED BELVAL



VELSEN TUNNELS, HOLLAND
(1100 tons BZ Steel Sheet Piling in lengths of 72′ and 90′)

BELVAL Z

COMPLETE RANGE OF SIZES
TO MEET ALL REQUIREMENTS
HIGH SECTION MODULI
LOW WEIGHT PER SQUARE FOOT



BELVAL P

FLAT SECTIONS
FOR CELLULAR CONSTRUCTION
LIGHT WEIGHT
HIGH INTERLOCKING STRENGTH
BEST DEFINED HOOKING

Manufactured by :

ARBED

ACIERIES REUNIES DE BURBACH-EICH-DUDELANGE
BELVAL WORKS, LUXEMBOURG

MONOPOLY OF SALES : **COLUMETA, LUXEMBOURG**

Agents for India :

SHANTA BROTHERS PRIVATE LTD.

Vaswani Mansions,
Dinsha Wacha Road,
Churchgate, BOMBAY-1

3, Hanuman Road
NEW DELHI

6, Russell Street
CALCUTTA-16

NATIONAL ELECTRICAL INDUSTRIES LTD.,

LALBAUG, BOMBAY 12.

Makers of

Power & Distribution Transformers
Electric Motors
Motorised Grinders & Polishers
Monobloc Pumps

Telegram : "NATELIN" **Telephone : 77391 (3 Lines)**

fungus can be avoided ?

THE BEST CEMENT WATERPROOFING COMPOUND

Do not neglect damp patches or corossive marks on the wall, it means the wall is being eaten by saltpetre and saltpetre has an insidious, wide-spread action. Patchwork repairs will not help. To repair a damaged wall effectively and permanently, plaster with CICO.

Better call us

THE STRUCTURAL WATERPROOFING CO., PRIVATE LTD.

21/1, DOVER ROAD, CALCUTTA-19

GILLANDERS ARBUTHNOT & CO., LTD.

ECLIPSE ENGINEERING COMPANY
BIRD & COMPANY (PRIVATE) LTD.
MARTIN BURN LTD.
R. M. & COMPANY

Selling Agents :

— For Madras, Delhi, U.P., Bhopal, Rajasthan, Jammu and Kashmir.
— For Bombay.
— For Punjab, Pepsu and Himachal Pradesh.
— For Bihar, Orissa and Assam.
— For M.P. (except Bhopal).

CHARMILLES

Specialists In

HYDRAULIC TURBINES

UNDER SUPPLY:

GOVERNMENT OF ANDHRA

For TUNGABHADRA H.E. SCHEME
TWO 12500 H.P. FRANCIS TURBINES

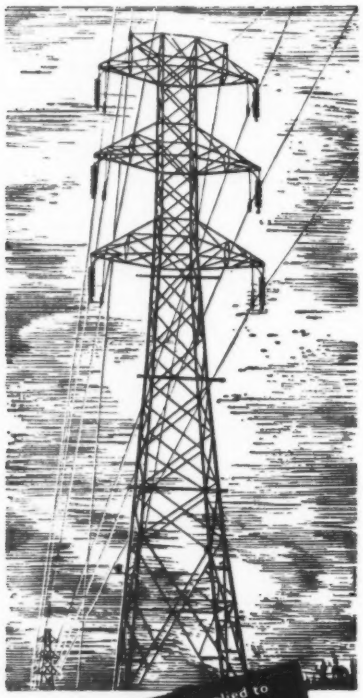
GOVERNMENT OF KERALA

For PORINGALKUTHU H.E. SCHEME
FOUR 13500 H.P. FRANCIS TURBINES

For NERIAMANGALAM H.E. SCHEME
THREE 23000 H.P. FRANCIS TURBINES

CHARMILLES ENGINEERING WORKS LTD.
GENEVA—SWITZERLAND
Sole Representatives in India : **KAYCEE INDUSTRIES LTD.**, P.O. Box 615, BOMBAY

THE BEST IS YET TO BE



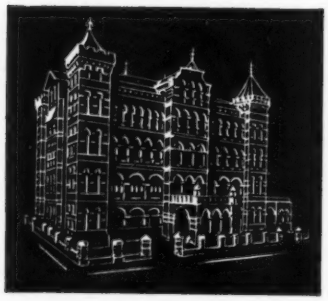
Landmarks as they are, Bhakra - Nangal, Damodar Valley and Hirakud are but a beginning - beginning of the onward march towards better living and prosperity. Today steals a march over yesterdays, only to be bettered by the tomorrows - bettered by the experience and confidence derived by our dedication. For the best will be when India meets the Great Challenge.

KAMANIS starting from the scratch, can now pride themselves in having a most uptodate factory where design, testing, fabrication and galvanising of Transmission Line Towers are all done under the same roof. Since the inception, they have designed 184 types of Towers, 92 types of substation structures and 28 types of Communication and Aerial Masts. Orders executed by KAMANIS and orders on hand aggregate 50,000 tons constituting 66% of the Nation's requirements.

THIS IS BUT A BEGINNING AND THE BEST IS YET TO BE

KAMANI'S TOWER
FOR THE NATION'S POWER

IN THE FOREFRONT
OF THE
INDUSTRIAL SCENE



KAMANI ENGINEERING CORPORATION LIMITED

Factory:
Agra Road, Kurla North
BOMBAY 37

KAMANI CHAMBERS
NICOL ROAD
BOMBAY

Branches :
CALCUTTA/JAIPUR/NEW DELHI/MADRAS/PATNA

INDIAN JOURNAL OF POWER AND RIVER VALLEY DEVELOPMENT

A MONTHLY DEVOTED TO DEVELOPMENT OF POWER & WATER RESOURCES IN ASIA

Editor : K. K. Sinha — P. K. Menon : Mg. Editor

VOL. VIII — **DECEMBER 1958** — **NO. 12**

SYMPOSIUM ON POWER DEVELOPMENT IN INDIA

CONTENTS

MESSAGES		1
INTRODUCTION		3
AT THE START OF A LONG JOURNEY	*Hafiz Mohammad Ibrahim*	5
POWER SUPPLY IN OUR NATIONAL PLANNING	*Manoranjan Datta*	7
POWER DEVELOPMENT IN INDIA: PRESENT POSITION AND PROSPECTS	*M. Hayath and S. Swayambu*	23
POWER REQUIREMENTS OF INDIA DURING THE SECOND, THIRD AND FOURTH PLAN PERIODS	*S. S. Kumar and A. Shankaran*	29
REQUIREMENT AND RESOURCES FOR POWER GENERATION IN INDIA	*A. Lahiri and A. Ghosal*	35
POWER DEVELOPMENT IN INDIA: PRESENT POSITION, PLANNING AND PROSPECTS	*J. L. D'sa*	53
POWER DEVELOPMENT IN INDIA	*A. K. Bhaumik*	55
SUPER-GRID SYSTEM FOR INDIA	*M. Hayath and V. Venugopalan*	59
SOME ASPECTS FOR POWER SYSTEM DESIGN	*H. N. Ramachandra Rao and B. N. Narayana Iyengar*	63
TEST ON 220 KV TRANSMISSION LINE TOWER	*G. R. Hukmani*	69
NEW TRENDS IN THE DESIGN OF AXIAL FLOW UNITS	*Piere L. Misson and Indru T. Advani*	75
POWER DEVELOPMENT IN MADRAS STATE	*V. P. Appadurai*	83
POWER DEVELOPMENT IN MADHYA PRADESH	*M. K. R. Menon*	86
REVIEW OF POWER DEVELOPMENT IN ASSAM	*G. C. Goswami*	92
DEVELOPMENT OF ELECTRICITY IN ANDHRA PRADESH	*V. Parvathesam*	94
POWER DEVELOPMENT IN THE PUNJAB	*S. Harbans Singh*	96
POWER FOR PROSPERITY: THE CHAMBAL VALLEY DEVELOPMENT SCHEME	*K. S. Sivaprakasam*	101
DEVELOPMENT OF HIGH PRESSURE THERMAL POWER STATION	*L. N. Misra*	106
OUR CONTRIBUTORS		112
Index to Advertisers		116

Editorial and Managerial Offices
6/2, MADAN STREET, CALCUTTA-13. PHONES : 23-1765 & 23-5855. GRAMS : TEKJOURN
Manager : B. Bhattacharya

Bombay Office
41, Hamam Street
Bombay 1
Phone : 252119

German Representatives
Linder Presse Union G. M. B. H.
Frankfurt/Main, Wittelsbacher Allee 60
W. Germany.

London Representatives
Walter Judd Ltd.
47, Gresham Street
London E.C. 2

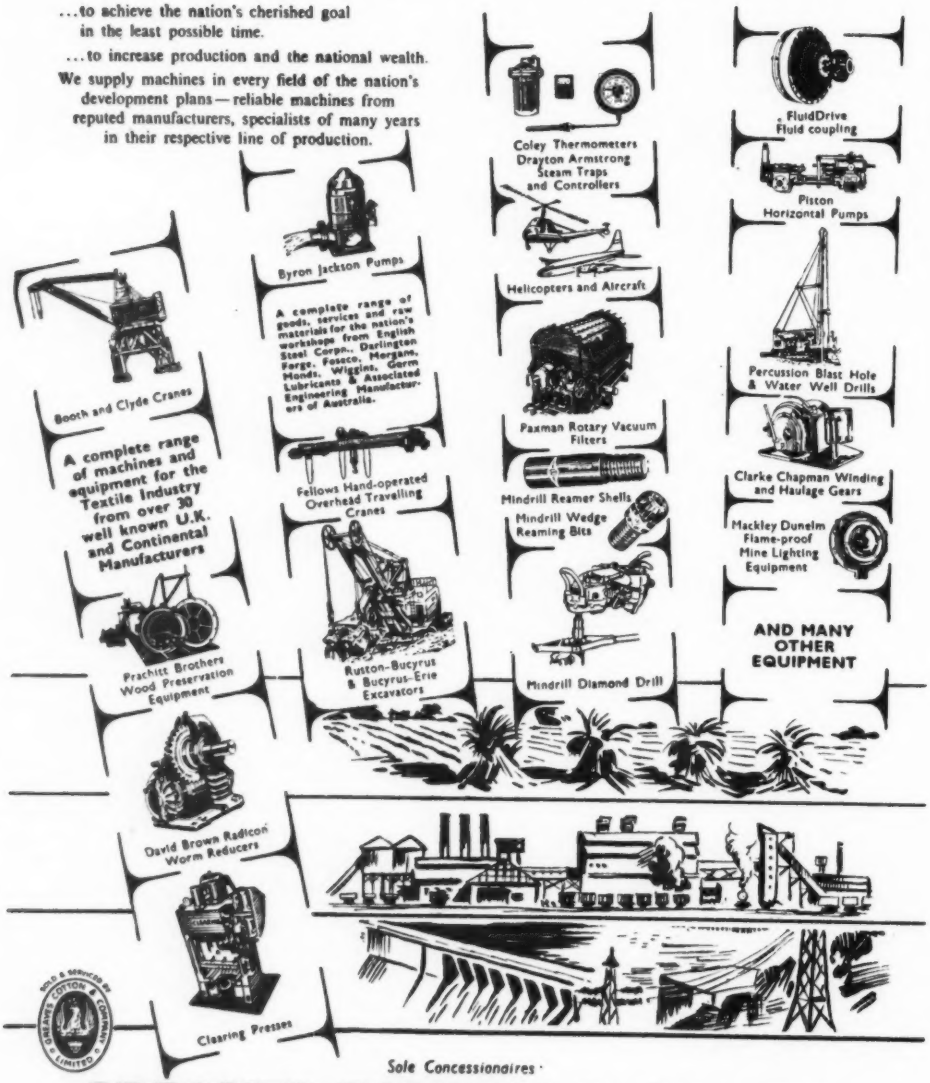
Annual Subscription : Rs. 20, £2 or $6.00. *Single copy : monthly issue* Rs. 2
This issue: Rs. 7·50 *Back issue at double rates*

Helping the Nation to help itself...

...to achieve the nation's cherished goal in the least possible time.

...to increase production and the national wealth.

We supply machines in every field of the nation's development plans—reliable machines from reputed manufacturers, specialists of many years in their respective line of production.


Coley Thermometers
Drayton Armstrong Steam Traps and Controllers
FluidDrive Fluid coupling
Byron Jackson Pumps
Piston Horizontal Pumps
Booth and Clyde Cranes
A complete range of goods, services and raw materials for the nation's workshops from English Steel Corpn., Darlington Forgr., Foseco, Morgans, Monds, Wiggins, Gorm Lubricants & Associated Engineering Manufacturers of Australia.
Helicopters and Aircraft
Percussion Blast Hole & Water Well Drills
A complete range of machines and equipment for the Textile Industry from over 30 well known U.K. and Continental Manufacturers
Paxman Rotary Vacuum Filters
Clarke Chapman Winding and Haulage Gears
Fellows Hand-operated Overhead Travelling Cranes
Mindrill Reamer Shells
Mindrill Wedge Reaming Bits
Mackley Dunelm Flame-proof Mine Lighting Equipment
AND MANY OTHER EQUIPMENT
Prachitt Brothers Wood Preservation Equipment
Ruston-Bucyrus & Bucyrus-Erie Excavators
Mindrill Diamond Drill
David Brown Radicon Worm Reducers
Clearing Presses

Sole Concessionaires

GREAVES COTTON & CO. LTD.

Bombay · Calcutta · Ahmedabad · Bangalore · Coimbatore · Kanpur · Madras · New Delhi

Ralli House, 16 Hare Street, Post Box 702, Calcutta 1.

Telegrams: "GREAVES" · Telephones: 23-2236. 23-2693. 23-3063

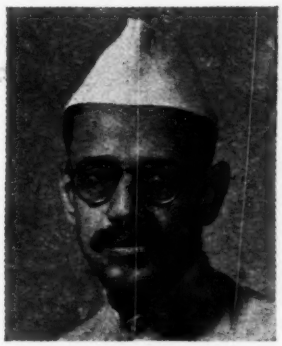
Messages

With the rising tempo of industrial development we have to ensure that the wheels of industry go round without let or hindrance. It is with this object is view that we have launched upon quite a few power projects in the country and it would be quite useful to study 'Power Development in India: Present Position, Planning & Prospects'. I am glad that the Indian Science Congress is holding a symposium on the 23rd and 24th January in Delhi for the study of this vital subject. I trust this will stimulate the interest of the general public. I wish the symposium every success.

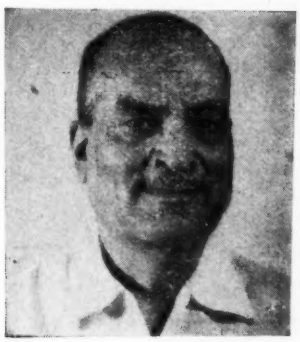
MORARJI DESAI
Minister for Finance
Government of India

I am glad to learn that the Indian Science Congress has organised an All India Symposium on "Power Development in India — Present Position, Planning & Prospects" and that the papers that would be read at this Symposium would be published in this special number. I dare say that Indian Journal of Power & River Valley Development is doing yeoman service in disseminating this knowledge.

In the context of the present shortage in foreign exchange, the problem of power development is both a challenge and an opportunity to the scientists and engineers to devise ways and means of making ourselves self-sufficient in this field.

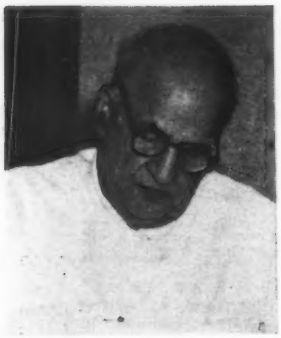


G. L. NANDA
Minister for Planning
Government of India



I am very glad to learn that the Indian Science Congress is holding a symposium on "Power Development in India" at its annual session to be held in Delhi and that a special issue of the Indian Journal of Power and River Valley Development will be brought out on the occasion. The subject of the symposium is extremely timely as power development is the key to general resource development of the country. For the last ten years feverish activity in this field has taken place in all the States of the country and it is time that a stock-taking should be made by those who have been responsible for the planning and execution of power projects. It is most important that in so doing we should try to integrate the State and Regional resources and needs within a general country-wide long-term perspective. Further, it is equally necessary that the different sources of power are carefully evaluated and their inter-relation in a power-generation programme scientifically arrived at. I am sure the eminent engineers and scientists will consider these aspects at the symposium. I wish the symposium all success.

B. C. ROY
Chief Minister, West Bengal



I am glad you are bringing out a special supplement of the 'Indian Journal of Power and River Valley Development' prior to the Annual Session of the Indian Science Congress at which a symposium is going to be held on power development in India.

The idea of getting a number of papers prepared by leading engineers on power development is an excellent one. I am sure your supplement will furnish useful material for the Congress and wish your efforts every success.

V. T. KRISHNAMACHARI
Dy Chairman
Planning Commission

I am very glad to learn that an All India Symposium is being shortly held under the auspices of the Indian Science Congress on Power Development in India. Ever since my first visit to Canada and the United States of America in 1939 I was convinced that to fight the growing poverty in India it was necessary to develop power side by side with irrigation. After Independence demand for power is doubling up practically every five years. Some doubts had been expressed in important circles in 1952-53 that the power we were then contemplating to generate on the D. V. C., the Hirakud and the Bhakra Nangal Projects would not be utilised. Even in that controversy I expressed a positive opinion that power will be utilised as soon as it is developed. Actual experience has corroborated the conviction I then held. At present not a kilowatt which is either generated or is proposed to be generated is going abegging.

As power projects take considerable time to plan and construct, it is essential that a long range view is taken of the likely demands in various parts of the country and the most appropriate steps that can be taken to meet this demand. Experts in many disciplines must join their heads together to assess the demand. I hope the symposium which is being held under the auspices of the Indian Science Congress will give a positive lead in the matter of future power development in India.

KANWAR SAIN
Chairman (Rtd),
Central Water & Power Commission.

Introduction

Having been encouraged by the success of the symposium on "Power and Water Resources of West Bengal" sponsored by this Journal under the auspices of the Indian Science Congress in January 1956 in Calcutta, we have collaborated with Dr. Manoranjan Datta, President of the Engineering and Metallurgical Section of the Indian Science Congress this year to organise the present symposium on a larger canvas, namely : Power Development in India : Present Position, Planning and Prospects.

Our grateful thanks are due to Hon'ble Hafiz Mohammad Ibrahim, Union Minister for Irrigation and Power, for readily acceding to our request to inaugurate the Symposium.

Initially it was contemplated to cover not only the aspects of generation and transmission but also long distance communication. But it was found that it would be much more fruitful if the discussion centred round only the generaton and transmission aspects of the problem, which provides a vast enough range.

Although very little time was given to the authors of the papers, they have responded splendidly as will be noticed from the contributions that follow. We thank them heartily as well as to the Central Water and Power Commission, the Central Fuel Research Institute, the Indian Institute of Science, the various State Electricity Departments and Boards and the leading private firms, without whose cooperation it would not have been possible to hold this Symposium.

The last decade has been a period of tremendous many-sided activity all over India. Naturally enough, power generation and distribution has not lagged behind, as it occupies a pivotal place in resource development. Today there is a veritable race between the various States to outpace their previous rates of development in this field. This indeed is a healthy sign. But the country being one and the resources of different kinds being unevenly distributed, it is important that an overall integrated development takes place and tendencies towards uneconomic self-sufficiency are avoided. While intensive efforts in each State are necessary, both in the field of planning as well as execution, these need to be harmonised in terms of a general framework of a national policy.

These above considerations are necessary to be kept in mind today for yet another important reason. Modern developments in the field of technology in power generation and distribution are vastly different from those of even the past decade, and they are still making rapid strides. The atomic age is having a great impact on the world of power development. Efficiency and economy of generation and transmission are thus greatly affected by researches. All these can be taken full cognisance of only in the context of the larger canvas of the entire country. If we fail to have this wider perspective at this stage of our national growth and remain preoccupied in narrow horizons, we shall be committing a grave error of judgement and imagination, for we shall not get such an opportunity again.

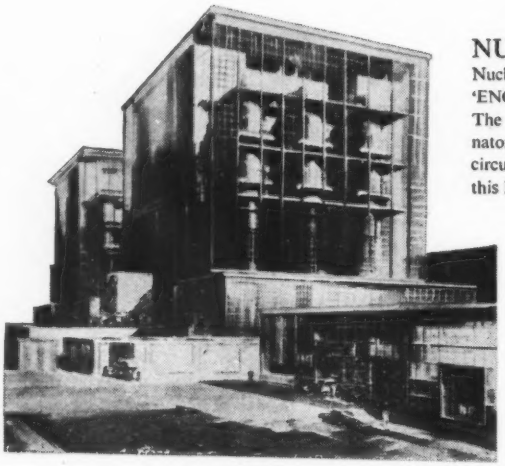
Let us hope this Symposium will help us to see more clearly the larger perspective in the field of national power development.

We gratefully acknowledge the help and cooperation received from the Indian Science Congress.

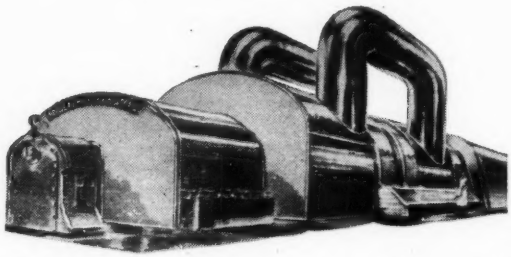
We hope to be able to publish a report of the discussions at the symposium at a later date.

'ENGLISH ELECTRIC'

Leads the field in EVERY phase of Power Generation

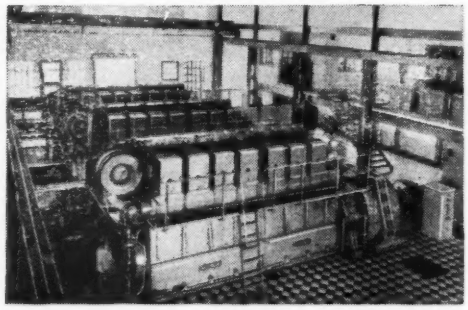


NUCLEAR. The first 500 MW Atomic Power Station (the world's largest Nuclear station) is under construction at Hinkley Point, U. K., by the 'ENGLISH ELECTRIC'—Babcock & Wilcox—Taylor Woodrow Consortium. The English Electric Company is supplying six main 93.5 MW Turbo-Alternator Sets, three 33 MW Variable Speed Turbo-Alternator Sets and a fifteen-circuit 275 kV duplicate Busbar Switching Station. The Reactors to be used at this Power Station will be of 'ENGLISH ELECTRIC' design.



STEAM. One of five 200 MW Steam Turbo-Alternators which the Company is supplying for the High Marnham Power Station, U. K. Early this year the Company received an order for two 275 MW Steam Turbo-Alternators for the New Blyth Power Station, U. K., and the sets are the two largest in-line turbo-alternators of their kind (50 cycles) in the world.

HYDRO. One of two 37.5 MW Water Turbine Generating Sets installed at Hirakud Power Station, Orissa. In the past 10 years the Company has supplied the entire plant for four major hydro-electric stations in India—Radhanagari, Nizamsagar, Sarda and Sengulam, and is manufacturing five—50 MW Water Turbine Generating Sets for the Rihand Power Station, U. P.



DIESEL. Three 'English Electric' Diesel Alternator Sets installed at Saateni Power Station, Zanzibar. The total output of the engines is 3,936 B.H.P. at 375 r.p.m. and the Station supplies the Island with a large part of its electricity.

THE ENGLISH ELECTRIC COMPANY LIMITED

(Incorporated in England. Liability of Members Limited)

New Delhi Calcutta Bombay Madras Lucknow

Manufacturers of the famous 'ENGLISH ELECTRIC' *CANBERRA Jet Bombers*

EEC-49

At the Start of a Long Journey

By HAFIZ MOHAMMAD IBRAHIM
Union Minister for Irrigation and Power

I am greatly honoured by the opportunity given to me to inaugurate this Symposium for which distinguished scientists and engineers have assembled here for considering the lines on which the planning of power development should proceed in future. It is a very important subject on which the Government of India and the various State Governments are keenly interested to receive your considered recommendations. I understand that a number of papers of high technical content have been contributed for this Symposium and hope that there would be keen discussions on all important aspects of the problem. In my brief address, therefore, I do not wish to go into any of the technical details of long-term planning for power, but would content myself with a reference to certain broad points relevant to this subject.

As you are no doubt aware, planning for any sector of a country's economy has to take stock of the needs of the community and aims at meeting them from the available resources in the best possible manner. Sometimes it is termed long-term planning, but any long-term programme naturally takes the present position and the short-term needs also into consideration. In the case of 'Power', we are almost at the start of a large expansion programme, and this, of course, is true of many other fields of activity such as heavy industries, mining, ship-building, etc. The total generating capacity in India at the beginning of the First Plan was 2.3 million kW and during the First Plan period 1.1 million kW was added, thus bringing the installed capacity to 3.4 million kW by the end of the First Plan. During the Second Plan, we have a programme for doubling it and it is possible that we may attempt another doubling in the Third if financial and technical man-power resources permit. If the Government's long-term objectives are to be fulfilled in respect of increasing the standard of living, we will have to maintain a rate of expansion of power facilities of about this order over several five year periods. To what extent such large scale development is possible and how and on what basis it should be planned is admittedly the responsiblity of engineers and planners.

So far, in planning our power projects, we have been chiefly concentrating on meeting the needs of each individual State from its own resources. It is not always possible that adequate power potential be found to the required extent within the respective state boundaries. I am advised that, on the basis of preliminary topo studies conducted by the Central Water and Power Commission, the total hydro-electric potential within our territory is of the order of 40 million kW and that there is every hope that more sites with additional potential may be found when detailed field surveys and investigations are undertaken. Besides, very large resources exist on the borders of India in the Himalayan region. We have also very large deposits of low grade coal which are suited to power generation in a large way if utilised at the pit mouths. If our present efforts to explore oil prove fruitful, there will be yet another source of energy. In the same way nuclear power will also play an important part in the future. All these are really resources which should be harnessed for the benefit of our people in different regions irrespective of state boundaries. I can assure you that with good will and understanding, inter-state cooperation to the maximum extent would be forthcoming and that the bounties of nature would be distributed to our people all over the country. I wish to commend to you, therefore, that in the course of your deliberations, you may bear this fact in mind and proceed on the basis of a regional approach to our resources development.

Another point, which I would touch upon and which has an important bearing on the future course of development of projects, is in regard to the great strides made in modern technology. The technique at our disposal, say, 20 years ago, can be considered outmoded now as far-reaching improvements have since been made. At the present time, we have at our disposal better tools and better methods and these will have to be brought into play in our project designs and construction. In the years to come, we can expect

to find even greater improvements. While considering some of our mighty power resources, the harnessing of which to-day may look formidable, let us not forget that future technological advances would be equal to the big task confronting us. As an example, I may mention the techniques of underground power stations, tunnelling works, super-high voltage transmission lines, etc., in which rapid progress has been made in the last few years. To-day in many hydro-electric projects, these techniques are being used. There is no reason why we should not adopt the most up-to-date techniques in our future programmes of development to our best advantage.

The commonly used index of power development in any country is the per capita production of electrical energy. As against a world average of about 670 kWh of electricity production per capita the figure for India is only about 34 kWh. In more advanced countries the per capital production of electricity is very high, for example it is 7,250 kWh in Norway, 5,450 kWh in Canada, 4,180 kWh in U. S. A., 3,950 kWh in Sweden, 2,000 kWh in United Kingdom and 850 kWh in Japan. Even if we are to aim at reaching the world average, not to speak of the level of the more advanced countries, it is indeed an uphill task. Nevertheess, our plans and our efforts should be directed towards that goal and in doing this we should plan on maximum utilisation of the power resources, hydro, thermal and nuclear power. As considerations of cost, technical feasibility and the time element are involved to varying extents in developing different types of resources and between one project and another, it will require considerable study to formulate an economic long-term plan. I have no doubt that this Symposium would be able to provide a pointer to the broad approach that we should make in regard to the problem just mentioned.

The greatest asset of this country is the enormous man-power at its disposal, but curiously enough we are short of trained technical and scientific personnel to-day. It should be our endeavour to transform many of our unskilled men into skilled workers and, again, the skilled workers into technicians. While the number of engineering schools and colleges is increasing and the people are getting experience in project works and the like, there is a definite shortage in the volume of technical man-power required for our projects. This imbalance between the demand on the one hand and the training of technical personnel on the other will take quite some time to be remedied and, in the meantime, we will have to face this real shortage. Many schemes have been suggested for training technicians in the works by means of intensive short-term courses and other methods. The responsibility for this rests with the project authorities. I know they have enough problems on their hands already and they may find it difficult to arrange adequate facilities for training personnel. However, I wish to plead strongly that the project authorities should consider this as an equally important responsibility to get men trained not only for their immediate needs but for future requirements as well. It is the skill and experience gained by our men in the projects now in progress that will help us in the long run. I have no doubt that this important point will receive adequate attention of our engineers.

Finally, I wish to remind you that in the planning and execution of power projects, you should always bear in mind the utlimate objectives for which you are working. In the field of power, the objective is to carry the benefits of electricity to the people for use in industry, irrigation or daily domestic life. In the ultimate analysis, it is one of the things intended to better the lot of the people. So in the course of planning, construction or operation of power projects, you should constantly keep in mind the social needs and objectives for which you are working. Let us take the case of rural electrification, which occupies an important place in our power programme. Due to low load densities and long length of lines required, it is said that rural schemes are not considered economical. Nonetheless, this cannot be sufficient justification for neglecting a vital line of development, but it calls for skill and ingenuity on the part of the engineers to devise ways and means of reducing costs and executing schemes to the maxmium extent. You engineers belong to a service department and the speed, courtesy and promptness with which you render that service, would go a long way to help people appreciate your role. The people should know that your chief concern is for their welfare. I am mentioning this point because a proper understanding by the people would help us to take up more and more projects for the good of all. To-day, even at the early stages of a planned economy in this country, we have been faced with many problems, such as paucity of foreign exchange, shortage of technical man-power and many others. We shall in time solve these difficulties, but let us not forget that more difficulties, possibly of a different kind, may crop up as we go along. We are at the start of a long journey and it would be more arduous as we go along, but we are not to be deterred in our efforts. America and Russia, we are told, are adding 6 to 10 million kW of new installed capacity every year, which is several times what we are doing, but that need not frighten us. Let such examples give us hope and confidence. Let us have faith in ourselves and there is no doubt we shall succeed in our endeavours.

In conclusion, please permit me to wish you godspeed and success in your deliberations at this Symposium.

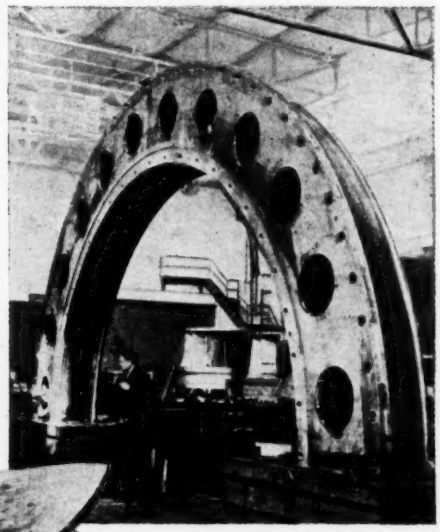
Large Kaplan turbine for India

NOHAB *turbines — always a step ahead*

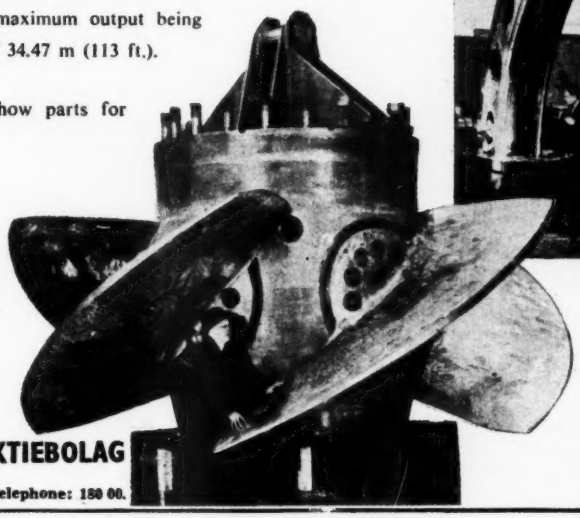
Last year, erection commenced on the Kaplan turbine, we have on order for The Panchet Hill Power Station, India.

The turbine will develop 56,000 HP at a net head of 24.7 m (81 ft.). The maximum output being 90,000 HP at a net head of 34.47 m (113 ft.).

The two pictures beside show parts for this turbine.



The runner during manufacture. Diameter of the runner 5.4 m (17 ft. 8 in).



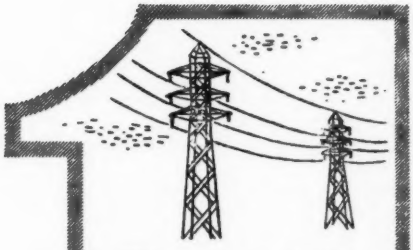
*The outer head cover during manufacture. In the background you can see two Francis runners intended for The Stornorrfors Power Station, Sweden, each with a guaranteed max. output of 200,000 HP—**the most powerful water turbines in the world.***

NOHAB

NYDQVIST & HOLM AKTIEBOLAG

TROLLHATTAN SWEDEN

Cables: NOHAB. Telex: 5284. Telephone: 180 00.



First with Aluminium Conductors

ISI

NICCO products are made strictly according to appropriate ISI specifications

NIC-11-58

NICCO is the pioneer concern that first manufactured A. C. S. R. and other Aluminium Wires for Power transmission and distribution in India. The scope and use of Aluminium Conductors are steadily increasing in this country and NICCO has also augmented its production capacity of these Wires. NICCO products are in extensive use all over India for their uniformly high standard of quality and dependability under all conditions of service. They are held in first preference by all discriminating Engineers.

NICCO WIRES & CABLES

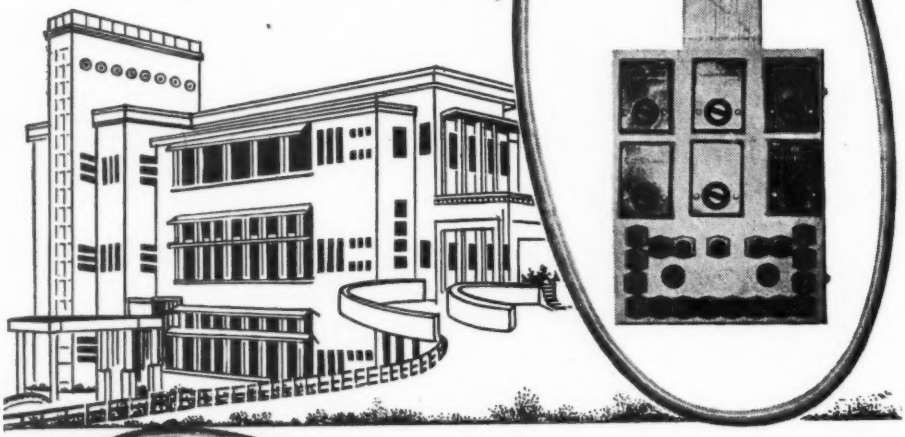
INDIA'S OWN

INDIA'S BEST

THE NATIONAL INSULATED CABLE CO., OF INDIA LTD.

STEPHEN HOUSE, DALHOUSIE SQ., CALCUTTA-1

This one is on the house!



COMBINING progressive engineering with modern materials and construction methods, ALIND's smart, brand-new office features the extensive use of aluminium as a practical, electrical and structural medium.

For instance, aluminium wiring (about 25,000 core yards) of ALIND KER-AL-LITE, the polythene insulated, polyvinyl chloride-(PVC) sheathed aluminium building wire, has exclusively been used for lights and fans, telephones and indicator circuits in "our new h.q.". If example is better than precept, you have before you, our own concrete example of practising what we preach!

ALIND KER-AL-LITE building wire is a light-weight, low-cost, dependable, electrical conductor.

Conforms to BS 2791: 1956 for aluminium conductors and BS 1557: 1954 for polythene insulation and PVC sheathing.

Design your next wiring job in ALIND KER-AL-LITE, the adequate and economical building wire.

THE ALUMINIUM INDUSTRIES LIMITED

India's largest manufacturers of aluminium conductors and accessories

KUNDARA (P.O.) KERALA STATE

Managing Agents: SESHASAYEE BROS.(TRAV.) PRIVATE LTD.

AL-565

Power Supply in Our National Planning

By Dr. MANORANJAN DATTA
President, Engineering and Metallurgical Section, Indian Science Congress

We meet to-day in a function of direct and intimate interest to our profession viz., Engineering and Metallurgy in our country. The General Session of yesterday was an august gathering where we invited our distinguished guests who are all worthy people of note and standing. This morning we hope to conduct the business of the day in a homely atmosphere.

When I realised that it would be necessary for me to choose a subject for an address which should be of general interest I found myself confronted with something of a problem. I looked back through the records and discovered that, with few exceptions, the addresses of my predecessors have been coloured by their individual experiences in the years preceding their election. No appologies are, therefore, needed for my having chosen the subject of "Power Supply in our National Planning". The importance assumed by the Planning and Development of Power in our successive Five Year Plans is unmistakable. I propose to take an overall national view of the present Power Supply position and its trend of future development. I shall try to approach the subject from a somewhat new angle, with special reference to certain selected aspects, particularly those which are now being accepted for achieving the target set before us in accelerating power developmet in our country.

Everything, great or small, has its phase of infancy. It appears rather clumsy and sketchy at the start, and slowly and gradually its trend, pattern and features become distinct and manifest. Power development on a national basis in our country cannot escape from this normal law of development.

Present civilisation owes its existence mainly to the utilisation of mechanical power by man. The steam engine altered the human outlook and paved the way for large scale industrial development and during nineties of the last century it came to be realized that the main source of power for economical use at home and in the industry would in course of time be electrical energy. The problems of high voltage generation and transmission of electric power from its source of production to different consuming centres has since engaged the attention of engineers and it has been found to be economical in many respects.

The economic prosperity of a country is, however, judged to-day largely by the amount of electricity it consumes. The per capita annual consumption in India is only 25 units whereas those of the other industrially advanced countries like England& U.S.A. are 1270 and 4400 respectively—the average annual consumption of electricity perhead of population for the whole world being 600. This is an indication of the leeway our country has to make up. Table I shows Energy Consumption and Resource of India in comparision with some advanced countries of the world.

Taking a very modest target of 100 units per head per year for India for the near future, it would mean that the country in order to raise its level of economic development would have to consume nearly 34000 million units a year which is equivalent to some 8000 MW of maximum demand at about 50% load factor and would call for an installed capacity of the order of 12,000 MW.

The problem of providing power at a cheap rate has been tackled in other advanced countries by concentrating generations for public supply purposes at a limited number of selected large stations. To enable the most efficient plant to operate at its best, as well as to keep the standby to a minimum, Generating Stations have to be linked by means of transmission network called grid systems. In consequence, the concentration of generation in large power stations and the construction of regional grids connecting them and the principal load centres by extra high voltage lines are in the forefront of India's plans.

Sources of Energy

Sources of energy may be grouped under two headings —non-replenishable and replenishable. Non-replenishable sources comprise coal and oil in which energy has been stored in the distant past. This energy can be used at any desirable rate until the supply becomes exhausted.

Although the tidal, wind, solar power and the natural heat of earth have been used on a small scale as sources of energy in some parts of the world, the power obtained from them is fortuitous and hardly economic for large scale production. Hydro power resulting from falling water is the only replenishable source of major importance. Such water power sources are being continuously replenished usually by the action of sun. This energy can be used continuously at a daily or yearly rate corresponding to the rate of replenishment. In India we are very well placed in regard to water power potential which has been estimated to be of order of 40,000 MW. (Table-1).

Indian resources of economically transportable low grade coal as distinct from metallurgical coking coal which is both in short supply and required exclusively for steel industries, have been estimated at 40,000 million tons. Taking about 3 tons of coal per 1 kW year, it should be possible to achieve an average output of more than 27 million kW over a period of about 500 years. Semi-bituminous and anthracite coal fulfil the requirements of power generation most satisfactorily although quite low grade coal can be effectively burnt. Transport of such coal to the generating stations would be a problem. Hence, mine head power stations have become very economical and eminently suitable for the loads of Bengal-Bihar Coalfield areas.

Power is also being produced from nuclear energy. Basic nuclear fuels are uranium and thorium. India's west coast is famous for its deposits of monazite sand. Cakes containing uranium and thorium are now being produced in India. It is estimated that the deposits of nuclear fuel could meet the demand for power for 1500 years. It is probable that nuclear power stations will be put in hand in India on commercial scale before long but as on present indications the overall cost per kWh will be appreciably higher than in the case of conventional coal burning or hydro stations. Moreover, to operate nuclear stations economically and efficiently a high load factor is essential and we have to defer construction of nuclear power stations on commercial scale until our grid and interconnectors grow more extensive and flexible.

Table I amply illustrates how favourably India is placed compared to other advanced countries of the world in respect of her water power potential and coal reserve.

From the Table II illustrating the relative economics of different sources of power, it may be concluded that we must develop our untapped hydro resources backed by coal fired power stations. In India the capital cost per kW of installed capacity for small and medium sized hydel power stations have more often than not been relatively higher than that for comparable thermal power station. But most of the large hydro-electric projects currently under execution and planning and also the future ones envisage to generate large amount of power and the capital cost involved in their implementation are quite competitive with and in many cases even lower than those of comparable pit head coal fired power stations. Besides, the longer life of the works, plant and installation of a hydro-electric project together with lower running cost results in lower overall cost of generation of hydro power. A matter of decisive importance, on which the prevailing shortage of foreign exchange focusses attention, is that whereas the investments on thermal schemes comprise a very high proportion of foreign exchange (since bulk of the cost is on plant and equipment which have to be imported) the investment of hydro schemes, being largely on civil works, the foreign exchange component of capital cost for hydropower station plant and equipment constitute a much smaller fraction of the total capital expenditure. It is, therefore, obvious that for a considerable period emphasis shall be on pit head coal fired thermal power and hydro stations all over India except for a few nuclear power stations in places far remote from coal reserve and water power sites because of its locational flexibility and/or for experimental purposes in regional grids where sufficient base load is available.

Zonewise Review of Power Development

The present and future trend of development of hydro and coal fired power potential of India are illustrated in the map with eight well-marked regions (Fig. 1). In the background of overall national economy the development of power all over the country, it has been recognised that the distribution of natural resources of power generation and the scope of utilization of power do not conform to the political divisions of the country into the various states. To secure optimum development and utilization of power potential, the All India Power Engineers Conference at Bangalore in January, 1957 have emphasised the need for co-ordinated planning and development of power on Zonal basis. In consideration of the concentration of hydro power potential resulting from the different mountain ranges, it has been found apt and appropriate to name the different power Zones after the respective mountain ranges to which their hydro potentials are due.

The Power Zones are:— (1) Southern-Western Ghat, (2) Northern-Western Ghat, (3) Eastern Ghat & Godavari Valley, (4) Satpura, (5) Western Himalayan, (6) Central Himalayan, (7) Eastern Himalayan & (8) A Zone comprising Assam, Manipore, Tripura and NEFA. The last Zone does not go by the name of any one particular mountain range as their scattered hydro power resources are to be attributed to different mountain ranges. Nevertheless, this Region may well be regarded as a power zone by the distinction that it stands apart from the rest of India in almost geographic and economic isolation.

Zone I

This Zone comprises the States of Madras and Kerala. Both these States have so far proceeded on hydro power development except for the city of Madras.

Table 1

ENERGY CONSUMPTION AND RESOURCES

Country	Energy Consumption				Non-replenishable energy resources					Replenishable sources	
			Electric consumption		Capital sources — Million kWh.					Hydro	
	Population 106	Total Consumption Million kWh/year	Total Million kWh/yr.	kWh per head/yr.	Coal	Peat	Oil	Oilshale	Natural	Potential in MW	Installed in MW
India	361	1200,000	9,100	25	1800×10^6	—	—	170×10^3	—	40,000	800
Britain	50	1750,000	64,000	1,270	290×10^6	13×10^3	—	—	—	500	270
U.S.A.	123	8800,000	544,000	4,400	2230×10^6	40×10^6	220×10^6	620×10^6	105×10^6	100,000	18,000
U.S.S.R.	193	4400,000	166,000	860	2900×10^6	230×10^6	272×10^6	2.5×10^6	10×10^6	60,000	1,700
France	41	590,000	41,000	1,000	42.5×10^6	6.5×10^6	100×10^3	2.5×10^6	—	4,500	4,500
Norway	3.3	100,000	22,000	6,600	—	—	—	—	—	7,500	2,900

Table 2

CHARACTERISTICS OF GENERATING PLANT

	Conventional	Nuclear	Gas Turbine	I.C. Engine	Hydro	Tidal	Wind	Solar
Capital cost — Rs./-kW ..	1000/-	2500-4500/-	1000/-	1000/-	1000-2000/-	1500-3000/-	1000/-	6000/-
Running cost — np per kWh.	2.5	2.0	3.0	6.0	0.5	0.5	0.5	0.5
Output kWh/year/kW	8000	8000	8000	8000	1000-8000	5000	3000	2000
Availability % ..	80-90%	80-90%	80-90%	80-90%	10-90%	30%	20%	20%
Usual type of load ..	Base	Base	Peak or Standby	Peak or Standby	Peak or base	Fortuitous	Fortuitous	Fortuitous
Time to start ..	2-3 hrs	2-3 hrs.	15 min.	10 min.	10 min.	10 min.	10 min.	10 min.
Response to varying load	Poor	Very poor	Good	Good	Very good	Very good	Fair	Fair
Location ..	Influenced by fuel, cooling water	Influenced by safety considera-tion & cooling water	Anywhere	Anywhere	Topo-graphical	Topo-graphical	Topo-graphical	Sunny climate
Size of unit ..	Upto 300 MW	Upto 100 MW	Upto 50 MW	Upto 10 MW	Upto 100 MW	Upto 100 MW	Upto 1 MW	Utpo 1 MW
Waste ..	Ash and flue gas	Radio active products	—	—	—	—	—	—

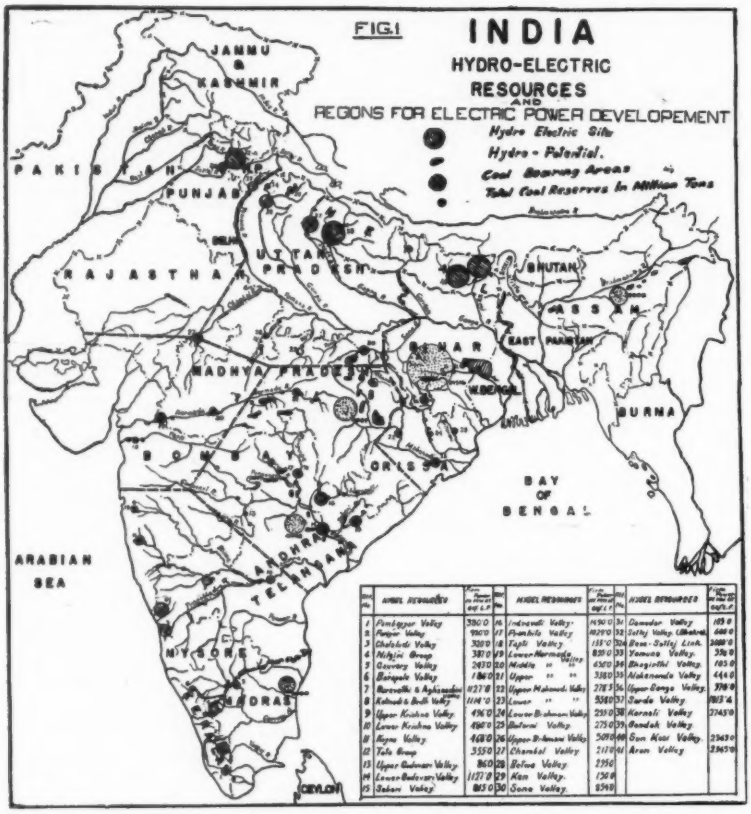


Fig. 1.

Important hydro stations in the Zone already in operation and under implementation are—Pykara, Moyar, Mettur, Papanasam, Periyar, Pallivasal, Poringalkuthu, Sengulam, Neriamangalam and Pennar. Madras city thermal station has also been extended by installation of another 30,000 kW set. The projected 250,000 kW. thermal power station on lignite mines of Neiveli has opened new possibility of low cost thermal power generation in the Zone. The large hydro power potential in the Southern portion of Western Ghats in this Zone can be harnessed in mutual collaboration of the two States, thus offering the possibility of development of a regional grid in this Zone which is already in the offing. This Zonal grid also holds prospect of interconnection with Zonal grid in Mysore, bulk of whose future requirement of power will be derived from proposed Sharavati Hydro Electric Project station. The aggregate installed capacity in this Zone at the end of first Plan period was 261,200 kW and is expected to be 10,10,000 kW at the end of second Plan period.

Zone II

This Zone comprising the entire State of Mysore and southern portions of Bombay and Andhra is also predominantly a hydro zone. The important power stations already in operation in this zone are the thermal power stations at Chola, Trombay, Hyderabad and Nellore and the hydro stations at Bhira, Khopoli and Bhipuri of Tata Power Co. The important hydro power sources in this Zone are—(1) Koyna (408,000 kW), (2) Kalinadi & Bedti (11,14,000 kW), (3) Sharavati Aghanashini (11,27,500 kW) (4) Upper Krishna (4,96,000 kW) and (5) Lower Krishna (4,80,000 kW). The first stage of Koyna Project already under implementatin under the second Plan envisages the installation of four 60,000 kW sets. Tungabhadra Project jointly undertaken by the Governments of Mysore and Andhra with an installed capacity of 20,000 kW will be completed within the second Plan period. The most important project undertaken by Mysore Government is Sharavati Valley project with two units of 89,100 kW each initially under the second Plan increasing progressively upto the ultimate total installed capacity of 891,000 kW. The Bhadra Project envisaging an installed capacity of 33,200 kW is also under implementation. The Bombay-Poona area in this Zone has a tremendous load potential which will have to be catered initially by harnessing the resources of Koyna and thereafter by implementing the Kalinadi group of schemes which being situated in the enlarged Mysore State will have to be implemented jointly by Bombay and Mysore to their mutual benefit. The long-term planning for power in Bombay-Poona area would also call for large-scale generation of power from nuclear resources as this area

is far removed from coal reserves. The installed capacity in this Zone at the end of first Plan period is 580,000 kW and that at the second Plan period is expected to be 1,070,000 kW.

Zone III

This Zone comprises the North-Eastern portion of Andhra, Eastern portion of Bombay and major part of Madhya Pradesh. The hydro power potentials in the Zone are mainly concentrated in the Godavari and her different tributaries aggregating 4400,000 kW. There are two major coal fields in this zone viz. Singareni in Andhra and Korba in Madhya Pradesh offering possibility of development of large scale thermal power. Hydro power sites so far developed in the Godavari basin is that of Machkund with an installed capacity of 51,000 kW under first Plan which is now being extended to its full plant capacity of 110,000 kW. Sileru first stage envisaging an installed capacity of 120,000 kW is now under implementation under the second Plan. The important thermal station in operation and under implementation in this zone are those at Khaparkheda (20,000 kW) and Korba (90,000 kW). There is also a proposal for a 60,000 kW. thermal power station at Birsingpur in this zone. The load growth in this region has been somewhat poor so far but holds forth possibilities of rapid increase in future years which will call for harnessing the hydel power potential of the Godavari basin and also large pit head thermal stations in Singareni and Korba coal field area. The installed capacity in this Zone at the end of first Plan period was 352,000 kW. and that at the end of the second Plan period will stand at 693,000 kW.

Zone IV

This Zone comprising the Northern portion of Bombay, Western portion of Madhya Pradesh and Southern portion of Rajasthan has a total hydro potential of only 1,895,000 kW and has no coal field. Power development in this Zone has hitherto been based on thermal generation inspite of the fact that this area is very remote from the collieries of India. The important thermal power station in this Zone is that at Ahmedabad. There is no hydro power station in operation in this region. Of the total hydel power potential of 1,895,000 kW in Narmada, Tapti and Chambal basins, only the last one having an aggregate potential of 217 MW is going to be harnessed to the extent of 92,000 kW initially under first stage of the second Plan as a joint venture between the Governments of Madhya Pradesh and Rajasthan.

Ths Panasa Project with a power potential of 450,000 kW in the Narmada Basin is being actively considered for meeting the load demands of Northern Bombay and Western Madhya Pradesh and when implemented would set the pace for further power development in this region

The installed capacity in this Zone till the end of first Plan period was 238,000 kW. and that at the end of the second Plan period will be about 422,000 kW.

Zone V

This zone comprises the major portion of Rajasthan, Delhi, East Punjab and Himachal Pradesh. The major hydro power stations already in operation in this Zone are:— Jogindernagar on Beas (48,000 kW), Gangwal (48,000 kW) and Kotla (48,000 kW) on the power canal taking from the Nangal barrage on Sutlej river. This Zone is also remote from the coal field. The major thermal power station in this zone is that at Delhi (62,000 kW). The entire hydro sources of power in this zone lie in the north. A beginning has been made under the Bhakra Project envisaging to generate 600,000 kW. at 60% load factor under the second Plan. These vast resources and its large network of transmission lines will establish their sphere of influence extending through the States of Punjab and Pepsu upto Delhi and Rajasthan in the south and into certain areas of Himachal Pradesh in the north. The demand of power beyond the scope of the Bhakra Project in this zone will have to be met by extension of Delhi thermal power station and also by further hydro development in the Beas Valley. Diversion of Beas water into the Sutlej basin behind the Bhakra reservoir will afford sufficient power to sustain the rapid pace of load development in this zone. The power potential of Beas basin has been estimated at 2,000,000 kW. The installed capacity in this Zone at the end of first Plan period was 232,000 kW and that at the end of second Plan period is expected to be 900,000 kW.

Zone VI

This Zone comprises the entire portion of Uttar Pradesh and Northern portion of Madhya Pradesh. This Zone has a total hydro power potential of 27,45,000 kW of which 7,90,000 kW lies in the Karnali basin, 18,15,000 kW in Sarda river, 5,58,00 kW in Yamuna, and 1,05,000 kW in Upper Ganga basins. There is no coal field in this Zone. The hydro power development in this zone so far are the seven power stations on the Ganges canal aggregating about 48,000 kW of installed capacity and Sarda (40,000 kW). Work is now in progress on Rihand project where two units of 50,000 kW each are expected to be commissioned by 1960-61 and 3 more units of even rating will be installed shorlty thereafter. Investigation is in progress on second stage of Yamuna (150,000 kW) and Ramganaga (75,000 kW). The major thermal stations in this Zone are those at Kanpur (80,000 kW) and Harduaganj (20,000 kW). Construction of power stations at Gorakhpur (10,000 kW), Mau (10,000 kW,) Sohowal (10,000 kW) and Mainpuri (10,000 kW) has been completed to provide power for tube-well. Work on additional generating units of 5,000 kW each at the first three thermal power stations is in an advanced stage and is likely to be completed by 1958-59. Augmentation of Harduaganj thermal station by installing two 30,000 kW sets is in progress. One more 15,000 kW set at Kanpur thermal power station is likely to be commissioned by early this year. The installed capacity in this Zone at the end of the first Plan period was 350,000 kW and that at the end of the second Plan period is expected to be 670,000 kW.

Zone VII

This important Zone with vast industrial potentiali-

ties comprises West Bengal, Bihar and the major part of Orissa above the Mahanadi river. The central and southern part of this region are rich in resources of coal and other mineral resources viz. iron, mica, copper, bauxite etc.

Progressive growth of thermal plant installations at Calcutta (435 MW) constituted major power development in this region till the post-war period when Damodar Valley Project covering the southern portion of Bengal and Bihar and Hirakud Project in Orissa were taken up. Uptil now 214,000 kW of installed capacity of D.V.C. is in operation of which 150,000 kW accounts for the installed capacity in Bokaro thermal station and 64,000 kW for hydro installation in Maithon and Tilaiya. Programme of power development of D.V.C. under SFYP includes extension of Bokaro thermal station by one 75,000 kW set, construction of a 150,000 kW thermal station at Durgapur and installation of a 125,000 kW set at proposed Superthermal station at Dugdha and installation of a 40,000 kW set at Panchet dam site power station. West Bengal Government is building up one 60,000 kW thermal power station at Durgapur and a 18,000 kW hydro power station in work Bengal Jaldhaka river. Bihar Government is building up one 30,000 kW thermal power station at Barauni under SFYP. In Orissa under the first stage of Hirakud Project an installed capacity of 123,000 kW at the main dam has already been commissioned. Implementation of the second stage which envisages the construction of the Chiplima power station (72,000 kW) at the end of the power channel from the main dam and also the installation of another 37,500 kW set at the dam under SFYP is already in progress.

In Bihar and West Bengal which have plentiful sources of coal, thermal generation forms the main-stay of its current development. Future development in the southern and central portion of this zone is expected to be based on the utilization of hydro resurces of the southern Zone and on the thermal generation to the extent necessary. The hydro power potential in the southern portion of this zone are those of lower Mahanadi (558,000 kW), Lower Brahmani (255,000 kW), Upper Brahmaini (509,000 kW) and Baitarni (275,000 kW). The Bhimkund project on the Baitarni has already heen investigated and the project report prepared for inclusion under the Third Plan to meet the growing load demand of Orissa and DVC area. As load demand increases, the utilization of hydro power sources in the Himalayan range will naturally have to be considered. The major water power sources due to eastern Himalayan range in this zone are those of Kosi (4,725,000 kW), Gandak and Tista (9,48,000 kW).

The installed capacity in this zone at the end of first Five Year Plan was 12,07,000 kW and that at the end of the Second Plan period is expected to be 19,45,000 kW.

Zone VIII

This region comprises the contiguous States of Assam, Manipur and Tripura can be considered as a separate unit for planning. Power development in this Zone is in a nascent state and consists of isolated small-scale development. The zone abounds in natural resources and power development at potential centres can advantageously be initiated by small and medium scale schemes. The Umtru Hydro-electric Project with an installed capacity of 8400 kW commissioned in 1957 is one such. Under SFYP a thermal station of 6000 kW will be installed at Umtinagar. About 17000 kW of plant is expected to be added by small schemes included under rural and small town electrification schemes. This Zone possesses vast resources of hydro-electric potential, but these resources have yet to be surveyed. On a very rough estimate the power potential of this Zone has been estimated to be of the order of 13,270,000 kW.

Present trends in Steam Power Generation

The inter-connection of large power stations and formation of different regional grids during the post-independence period has led to the adoption of higher rating of turbine and alternator for reasons of overall economy in respect of capital as well as maintenance and operational expenditures. The sizes of turbo-alternators now being installed in India in the different major power stations feeding the different regional grids ranges between 30 and 75 MW. The projected thermal power station of Damodar Valley Corporation at Dugda will have the largest set in India viz. 125 MW. Thermal conditions of the steam of the sets being installed at present is considerably in advance of those of previous sets. The turbine inlet steam condition at Bokaro thermal power station commissioned in 1952 is 850 lbs/sq. in and 900°F as against 1450 lbs/sq. in. and 1000°F. of 75 MW set now being installed at D. V. C.'s Durgapur Power Station.

During the last decade considerable investigation has been carried out in order to establish in practice the thermal gain from a change in steam cycle. Use of Rankine cycle with super-heat to prevent condensation during passage through turbine or Reheat cycle to avoid excessive moisture without having a high initial temperature are now greatly influenced by the metallurgical improvements which enable very high initial steam temperature. A recently projected 275 MW set has a pressure of 5000 lb/sq. in. and initial temperature of 1200° F· with two reheats to 1050° F. (Philadelphia Electric Co.) Majority of modern high efficiency plant use re-generative cycle by bleeding steam from one or more points as it passes through the turbine and using this steam to heat the feed water.

Though the use of field cycle is in the experimental stage, it has great possibility as it is claimed to give better efficiencies than regenerative cycle at high temperature (overall values of about 45% is claimed for 1050°F). Exhaust steam from turbine is used to supply super-heat. The dry saturated steam leaves the compressor and is partially super-heated by the exhaust and further by fuel fired super-heater. The steam then passes through the turbine which it leaves at a high temperature and flows through the regenerator and back to compressor (Fig. II).

In this country where vacuum condition is lower

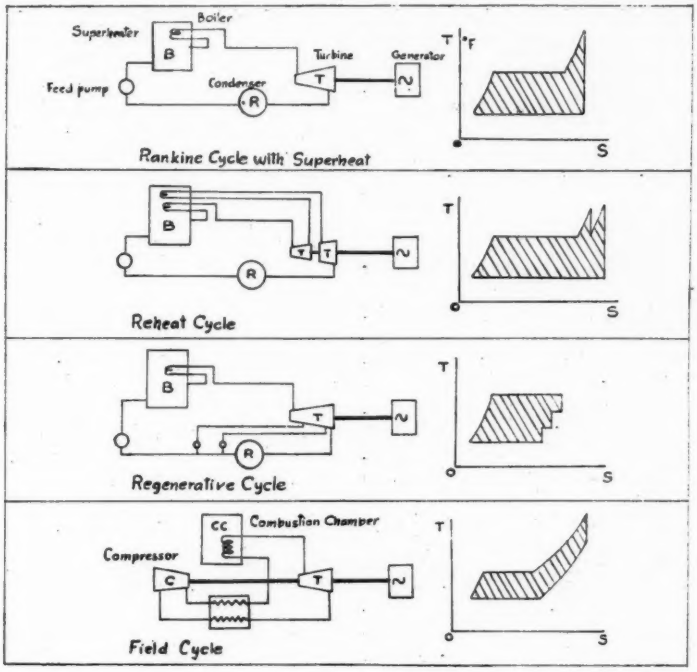


Fig. 2

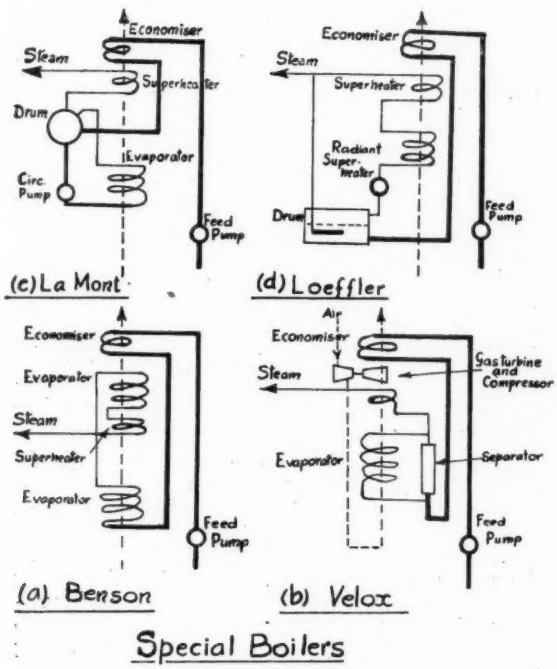


Fig. 3

than that in cold countries, single cylinder sets upto 50 MW have been adopted. Two-cylinder 1500 lbs./sq. in. 100 MW turbine have been built with three bearings and rigid coupling with high pressure and low pressure cylinder to achieve optimum size. Three-cylinder sets with double flow exhaust for 900°F and 1500 lbs/sq. in. steam are available for still higher rating. The cylinder design with either double or triple flow exhausts have been developed for very large reheat machines.

200 MW tandem compound turbines for steam condition of 2400 lbs/sq. in 1050°F with reheating steam are already being manufactured for British system. Design for 275 MW tandem and 550 MW cross compound units are being examined in detail, while application with initial steam pressure beyond 3000 lbs./sq. in. are in course of development.

The air cooled generator is no longer an accepted practice for large unit. Hydrogen cooled machines were going into service with hydrogen pressure upto 30 lbs/sq. in. The Hydrogen cooled units of D. V. C. at Durgapur P/S shall be using a pressure of 30 lbs/sq. in. Recent developments in the use of pressurised direct gas cooling of the rotor winding and pressurised liquid cooling of stator bars now enable, for example a 200 kW generator to be built with a rotor of almost same dimensions as of a 60 MW generator of early post war design.

Turbovisory instruments are now provided for all large sets to record and observe shaft eccentricity, differential expansion between turbine and cylinder, shaft speed etc. Nearly all plants will now operate at 3000 R. P. M. and 1500 R. P. M. plants will become increasingly obsolete as the inherent advantage of high spindle speed is to reduce plant size and initial cost.

Boilers :— The conventional boilers for a modern power station comprise a combustion chamber with coal or oil firing (stoker or pulverised fuel fired) from which hot gases pass through suitably disposed heating tubes steams drums, economisers, air-heaters, super-heaters, reheaters etc. Normal rating is 300-600 kilo lb./hr. The largest boilers in use in India at present are at Trombay having a capacity of 600 kilo lb. /hr . The boiler unit of Durgapur will be of 730 kilo lb./hr. out-put.

Boiler combustion technique is now considerably advanced. Majority of boilers having evaporative capacity above 300 kilo lb/hr. are now-a-days pulverised fuel fired. The chain grate or spreader stokers are limited to 150-250 kilo lb/hr. out-put. Dry type furnaces which is suitable for any type of coal is now-a-days giving place to slagging furnace producing hard granular ash which can be easily disposed of as an industrial material suitable for building and road construction. Slag furnace can now be designed to burn coals of much higher ash fusion point. The development of cyclone furnace for burning of high ash content low fusion point coal for stoker fired boiler and its adoption to p. f. firing gives high rate of melting. 70% to 80% fly ash could be melted by cyclone firing as compared to 40 to 50% by conventional firing in slagging furnace. So far as part load behaviour is concerned, such furnaces are satisfactorily operating upto 40% of load and even lower. Slag type furnace has made rapid strides and majority of continental boilers above 150 kilo lb./hr. are equipped with such furnace. A mechanical and electrical dust extractor with pf. boilers have proved very successful. Water level is now-a-days televised and remote controlled sequence operated soot blowers have become a part and parcel of large boilers.

Special Boilers:— Various special type of boilers have been devised to generate steam of very high temperature and pressure for quick starting. All employ forced circulation of water enabling smaller tubes, quicker starting and less troubles from scaling. (Fig. 3).

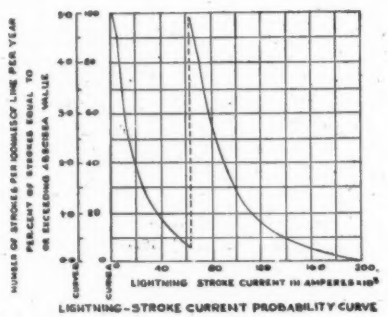

NUMBER OF STROKES PER 100 MILES OF LINE PER YEAR
PERCENT OF STROKES EQUAL TO
OR EXCEEDING ABSCISSA VALUE
CURVE A
CURVE B
LIGHTNING STROKE CURRENT IN AMPERES
LIGHTNING-STROKE CURRENT PROBABILITY CURVE

FIG. 4

Benson Boiler has no drum: The water is evaporated in main tubes and then super-heated. It was originally designed for a pressure upto 3000 lb./sq.in. but is now being built for conventional range of pressure too. It can raise steam nearly at the rate of 550 kilo lbs./hr. at a subcritical pressure. It can be started in about 15 minutes.

On the continent of Europe a number of Velox Boilers and power plants are in operation in steel industry. These boilers are very useful as standby plant in hydro electric stations. It is designed for pressure combustion in a combustion chamber where pressure is maintained at 35 lb sq. in. by an air compressor. The compressor is driven by a gas turbine supplied with furnace gas. A 10 kilo lbs./hr. unit can be brought from cold to full pressure in about 4 minutes.

In Loeffler Boiler a turbine driven feed pump circulates the steam through super-heater. Sudden demand for steam could be met by increasing the speed of pump. Lamont Boiler is a forced water circulation boiler where circulation can be increased upto eight times the out-put. A 220 kilo lb/hr. boiler can raise steam from cold in 12 minutes and from warm standby condition in 4 minutes.

The availability of modern boilers is very high being as high as 90% for mediocre grade coal. This is quite comparable to turbine availability and has led to the popularity of unitisation of boiler turbine thus resulting in considerable simplification and economy in pipe work and valve arrangement.

Regarding cooling tower, an important annexe of steam power station, R. C. C. hyperbolic type is becoming very popular in India due to the scarcity of cold clear circulating water. The size of cooling tower is increasing with the capacity of power station and cooling tower as high as 200 ft. has already been built in India.

Present Trends in Hydro Generation

The design of hydraulic plant has gravitated more towards the adoption of large out-puts concentrated on one shaft and turbines upto 150,000 bhp or more have become current practice, if other conditions permit. In India the largest unit so far in operation is 37,500 kW. at Hirakud. Some of the hydro-electric power stations now under implementation will have units of still higher rating viz. Bhakra with 90,000 kW unit with heads ranging between 515 and 275 ft., Koyna with 60,000 kW unit at 1500 ft. head and Rihand with 50,000 kW with heads ranging between 250 and 143 ft.

Under conditions of varying loads and heads, the automatic adjustment of runner blade angles is of paramount importance for achieving high efficiencies over wide range and to have freedom from cavitation and vibration. At present, adjustable runner blades for use upto 200 ft. head is available. Advancing scheme and research work in the field of hydro dynamic problems will probably succeed in the future to increase the working pressure limits for feathering propellors much higher.

In high heads ranging between 600 and 6000 ft. the Pelton or impulse wheel type turbine was almost exclusively used till a few years ago. This high pressure field is now invaded by reaction turbine either of

horizontal or vertical type for operation upto about 1400 ft. head. The application of judicious designs with the use of appropriate high tensile and stainless steel have permitted the adoption of much higher speed for both turbines and generators resulting in h gher efficiency and compact plants.

Important strides have been made in Europe in the domain of harnessing of low heads by means of Axial Flow Turbines. The most remarkable development is the design of the so called "Micro Power Stations" provided with Bulb Units having induction Generators rotating in oil.

This development permits the harnessing of head drops which would otherwise be beyond the scope of economical generation. These units possess a lacuna that they cannot be utilized in isolated networks. Nevertheless, where there exist powerful electric grids, the plethora of falls all over India could be tapped in order to augment India's power resources. These units will certainly have a greater role to play once India completes the formation of the zonal grids.

Still another new design has been put forward for low heads having a horizontal turbine of the Kaplan type and a conventional generator lodged in an upstream pier. The generator rotates at a higher speed as compared to the turbine thanks to the presence of the speed multiplier. This unit offers considerable economy as compared to conventional plants.

Some plants are completely and some partially arranged underground in India but advantage of greater effective use of available head and saving in steel and penstocks have to be carefully weighed against costs of underground construction work on pressure shafts, access tunnels etc., since under conditions obtaining in India, these can be considerable.

There are two less well-known forms of water power viz. pumped storage and tidal power projects. They can assist steam and hydro-electric stations in difficult periods of heavy demand and can utilize energy which might otherwise have been wasted in tidal or 'run-of-river' hydro-electric station during light load periods. In France, a single basin ebb tide working tidal station on the Rance has started functioning. But a tidal scheme would be economic only if the cost of tidal energy absorbed by the system were less than the price of coal delivered to the station. But such possibility is extremely remote in India.

Although there are many economic and other problems, associated with the effect of pumped storage on thermal plant operation, it is safe to conclude that with an appropriate choice of load factor and capital investment approaching that of an equivalent steam station, the rapid availability and ability to meet unexpected plant break-downs or demands would make pumped storage worthwhile and might reduce the cost of producing electrical energy from the system as a whole. There are two types of installations for this purpose, one where turbines and pumps are independent, the latter being driven by the generator used as a motor and the other one where the turbine is reversible for pumping purpose. We have scope for pumped storage in many of our large multi-purpose projects.

Comprehensive automaticity which is very much in vogue in modern large power plant is also being introduced in India to enhance the safety factor. This is necessary as continuous concentration on proper supervision for day and night service in isolated localities is difficult. Such automaticity comprises opening of valves, priming of pressure ducts, checking of bearing and cooling systems, starting of governor gear, release of brake, synchronising and loading up. The reverse cycle should safely provide against normal emergency shut-down, run away and all electrical failures.

Present Trends in Transmission and Distribution

As the electric power supply industry grew, the technology of transmission improved and developed. The progress of generation has been a fairly continuous process but the development in transmission was spasmodic.

The most obvious application of H.V. system is in the transmission of bulk power from a hydro-electric station or from a large aggregate of thermal generating plants on a coal field to the load centre for consumption or to inter-connect power stations to reduce total amount of standby plants.

In India problems arise and will continue to arise from transmission of large blocks of power over large distances. Stability and line regulation will in these cases be the criteria of design so that it will be common to find extensive use of synchronous condensing plant in our future regional grids.

Choice of Voltage: The engineers charged with the responsibility of developing system at minimum cost generally hesitate to take any ambitious step for developing high voltage netwrok as it involves large initial capital out-lay.

In the great majority of H. V. systems of our country the design is considerably influenced by past developments, as future possibilities are far from clear. Hence, two courses are open, one being to extend whatever systems already exist and the other being to provide for a new system of higher voltage. Short-term planning will ideally suit the former with the result of congested development; whereas a long-term planning (which is considered essential as the demand of power in this country is expected to double in 5 to 6 years for a considerable period from now onwards) leads to second course involving considerably heavy initial capital expenditure but will pay in the long run.

A ratio of 2 for the voltage of new system to old system was frequently adopted in this country in the past but such low ratio does not suit satisfactorily the paralleling of systems owing to the reactance of the intervening transformers. Experience shows that a ratio of 3 or 4 will suit our country satisfactorily.

132, 110, 66, 33, 11 and 6.6 kV. lines have so far been extensively used in this country. The selection of one of these preferred standard voltages for a new installation is desirable for India.

With regard to the choice of voltages above 200 kV the voltage level is basically guided by the availability of accepted designed plants as the curve of the cost of transmitting a given amount of power for such voltages varies only very slightly with the voltage level. Sweden which is most advanced in H.V. transmission system has 1000 miles of 400 kV line carrying several thousand of mega watts. Plans are being made for an A. C. system at about 600 kV. In India 220 kV. lines are being erected.

Insulation Level : For entirely underground system the insulation level is dictated by the switching surges whereas for overhead lines both lightning and switching over-voltages will occur. Lightning tends to produce voltages almost independent of system voltages whereas switching surges are generally proportional to the system voltages. So far as switching surges are concerned a maximum of 4 times the normal phase to neutral peak voltage has been experienced in inductive circuits such as idling transformers, but with regard to the amplitudes of lightning surges it is very difficult to predict. Statistics of the magnitude of stroke current and its frequency distribution are now being collected by different supply organisations over this country. The average earthing resistance in a particular region may be easily determined and hence from frequency curve the number of strokes that will produce voltages in excess of design values may be calculated. (Fig. 4).

Thus one approach to the choice of insulation level is now-a-days to select an impulse level related to nominal peak voltage by a factor exceeding the highest switching over voltages expected and then to determine the probable lightning faults for such an insulated system. If this number is too high the inslation level must be raised or the nominal voltage of the system should be increased to take advantage of the increased insulations.

Good results have been obtained by shielding the substations and part of adjoining lines with over-head ground wire and co-ordinating the insulation level at the entrance of sub-station with the terminal plant.

Regarding the basic insulation level for different standard transmission voltages, there is a tendency in America to reduce it in effectively grounded system. In such systems a protective level of 80 or even 75% of American standard value can be obtained with modern lightning arresters, and the insulation level of high voltage equipment can, therefore, be reduced to the same extent.

Switchgear : Very considerable progress has been made during the post-war years in the design of high voltage switchgear in technically advanced countries.

Increased short circuit capacity breakers at 132 kV is available upto 5000 M. V. A. and for 220 kV system 15,000 M. V. A. breaker with rated breaking current of 33,000 A.

Out-door 132 kV air blast circuit breaker have recently been introduced in this country. Previously majority of designs incorporated radial flow interruptor while the latest design provides for axial flow interruptor exclusively. The increased length and weight of the insulator necessitate the use of tubular porcelain instead of cap and pin type insulator.

In some of 132 kV and 33 kV systems small oil volume circuit breakers are being used. Since in this type of breaker the arc control device is enclosed in minimum amount of oil, there is less fire-hazard. This point has always been exaggerated though there have been very few fire-hazards with bulk oil type which are still in use in large number in the country with very good service record.

Most of the 66 or 132 or 220 kV circuit breakers are now-a-days provided with automatic reclosing device inspite of the fact that there is always a risk of about 25% of the cases of reclosure being unsuccessful due to persistent fault and such condition always leads to greater disturbances. The reclosure should be very rapid and generally recloses after a dead time of say 8-10 cycles.

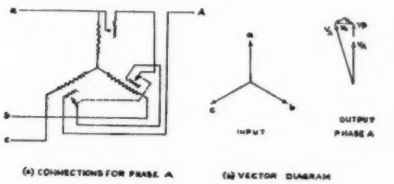
In modern power-stations the 11 kV circuit breakers are exclusively of air break type. The space factor is better because air breakers could be stacked in double or even in triple tiers. The general trend so far as in-door type distribution cicruit breakers are concerned is towards the increasing use of vertical isolation.

So far as 11 kV rural distribution is concerned, fault currents are generally very low and pole mounted circuit breakers with auto-reclosing devices are generally used for teeing off. In order to obtain cheap protection H. V. fuses are used extensively, liquid and expulsion types of fuses being used quite satisfactorily where short circuit current is low.

Transformers : Transmission transformers do not normally operate on continuous full load and substantial economy could be derived in capital out-lay by utilizing fully the thermal capacity of transformers to meet the daily peak load. The practice is fast becoming current in U. S. A. and also in Britain not to accept the name plate rating of transformers as anything but a basis of calculating allowable loading conditions. The development of cold-reduced, grain oriented, electrical sheet steel allow increased flux density for a given core size and thereby proportionate increase in rating for the same weight could be achieved. Nitrogen atmospheres are also being introduced. This permits higher winding hot spot temperatures and hence greater K.V.A. ratings for certain weight of material; it also reduces acidity to a negligible proportion because of exclusion of oxygen from the oil. The availability of excellent range of surge divertors accurately co-ordinated with impulse strength of the

windings and closely coupled to the bushings instead of being near the line terminals has permitted reduced insulation reinforcement. Improved design technique aided by the availability of better quality steel has caused reduction of 20% iron losses and 15% in the copper loss since 1949. Transformer ratings which were considered a few years ago as impossible to make and transport as three phase units are now very common.

To control distribution of power between parallel circuits coupled by transformer the use of inphase taps for voltage regulation is ineffective. Quadrature booster is necessary for such purpose. There appears to be certain amount of technical shyness about the use of quadrature booster in this country which are transformers with winding capable of transferring voltage from phase to phases (Fig. 5).



TYPICAL BOOSTER FOR IN-PHASE AND QUADRATURE CONTROL

FIG. 5

The successive five year plans of India will necessitate a great increase in number of sub-stations, both in rural and urban areas and hence the role of distribution transformer will be ever increasingly important in respect of cost of distribution of electricity. The Indian manufacturers should immediately in collaboration with different supply organisations agree to a standard specification for distribution transformers as such introduction will lead to repetitive manufacture of transformer to standard design and will thus reduce the manufacturing time cycle to lower the unit cost.

Copper wire or strip with the coating of Polyvinyal acetal are being introduced in the manufacture of distribubtion transformer in place of paper covered wire or strip for better winding space factor leading to reduction in weight of steel and copper. The use of Silicones as insulating material and mechanically joined pressure connections are expected to greatly reduce the cost.

The electronic digital computor is being used to arrive at optimum transformer designs to satisfy the manufacturers' techniques and customers' specifications quickly, thereby reducing the cost of product. India should not lag behind in this respect.

Relaying and ultra-rapid Reclosing : It is surprising that it take a long time to obtain general acceptance of idea that relaying and switching have more to do with the determining of how many and what kind of transmission lines are needed to deliver a specific block of power than size of conductor and other physical characteristic of transmission line. The function of a relay-breaker combination is to disconnect the line in trouble as quickly as possible to arrest even small dimension of damage and then to reclose with minimum possible delay, perhaps so fast that no effect of interruption could take place.

To match circuit breakers having a total break time of about 3 to 5 cycles, the application of protective equipments are limited to carrier current equipment (*a*) either phase comparison or impedance measurement principle, (*b*) impedance distance relays coupled with intertripping by means other than carrier current and (*c*) balanced protective devices for parallel feeders. Carrier current protection using the phase comparison method can provide very rapid simultaneous operation of the circuit breaker for a length of line between 20 and 100 miles. Below 20 miles, pilot wire protection is often cheaper and above 100 miles the problem of charging current and signal attenuation becomes difficult.

During recent years there have been no outstanding changes in the basic principle or method of operation of distance protection, but there have been lot of improvement in the design of relays. Where carrier protection is not economically justified 3 zone distance protection with various refinements to maintain stability during phase swinging is in common use in conjuction with slow speed protective devices like induction relays for back up or directional purposes.

Where possibility exists such as one line connecting a hydro-generating station to its system, single pole switching with high speed reclosure may be explored, otherwise if the major portion of the load is disconnected the generator will speed up rapidly not to permit high speed reclosing. But under single phase to ground fault the stability can be maintanied if only faulty phase is tripped and reclosed by necessary phase selector relaying equipment. For any other kind of fault all the phases tripped but not reclosed.

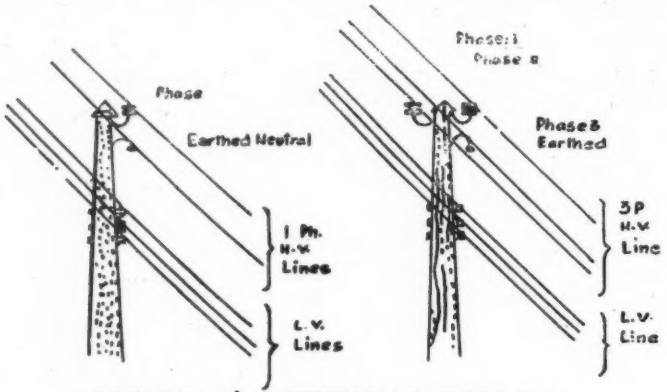
Rural Electrification: While speaking of rural electrification in many parts of India, it is worth mentioning that so long it was the practice to select the more remunerative places here and there and to electrify them piece-meal. Though economically attractive from a short term view. it entails moving of construction staff unnecessarily over the same region at frequent intervals. But considering that we are embarking upon large scale electrification. it is felt that a complete survey should be undertaken, on the regional state board basis. It may be devided into several sections and mileage of mains required for each section may then be assessed. Each section could be given figure of merit represented by the number of premises which could be connected for each mile of mains. Section could then be selected in order of this figure.

Economy in rural electrification is an absolute necessity and so use should be made as much as possible of the same pole to carry high and medium voltage lines. without the use of guard wires. For limited amount of medium voltage line aluminium conductor is being used in place of copper and the use of steel conductor for some of the single phase high voltage spurs is being introduced Fig. 6A. Electricity supply

lines may be allowed to follow the same route where telephone lines exist and vice versa. Joint construction or use of poles owned by one of the two parties viz. Electricity Board and P & T will render rural electrification economically feasible.

The loading conditions in our country are less severe than in Britain and there is also less difference between loaded and unloaded conditions The present method of calculating the factor of safety of lines assuming worst wind load to occur at minimum temperature when the conductor stress is high, is very uneconomical. Considerable economy may be effected in the capital cost by adoption of the modification discussed in the Author's article published in Electrical Review May, '51. The apprehension that vibration would result due to higher tensioning of the line is unfounded as with the span lengths used for 11 kV construction no trouble due to vibration has been reported. It is recommended that F.S. should not be less than 4 for normal everyday condition and that the tension during the worst load condition should not be more than 60% of ultimate strength. The worst load condition for each zone should be prescribed by an official regulation having reference to actual climatic conditions. The normal every-day condition for West Bengal for example may be taken as 90°F. without wind.

For rural distribution choice of protection is limited by economic consideration. Co-ordinated use of an



COMBINED H.V./L.V. OVERHEAD LINE CONSTRUCTION

FIG. 6a

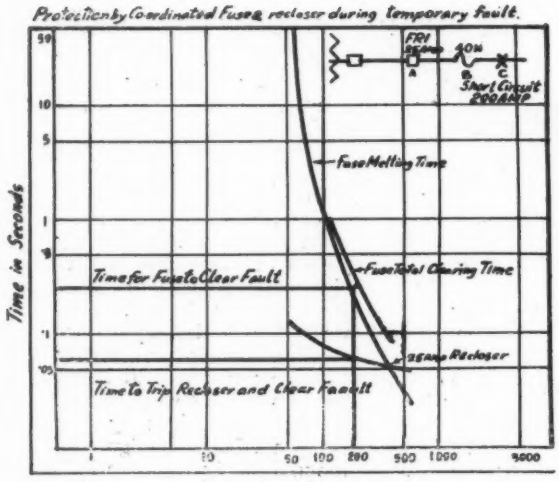
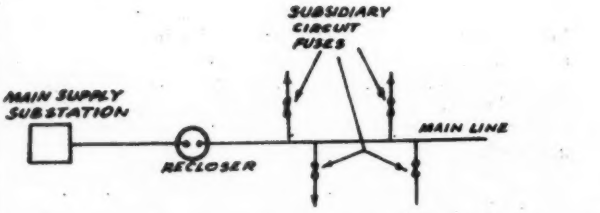
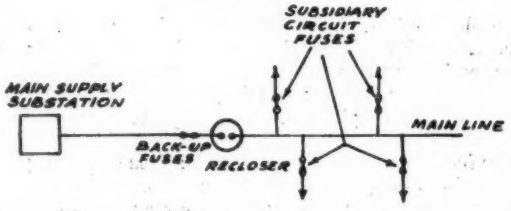

Protection by Co-ordinated Fuse & recloser during temporary fault.
Time in Seconds
Current in Amperes
Fuse Melting Time
Fuse Total Clearing Time
Time for Fuse to Clear Fault
Time to Trip Recloser and Clear Fault
Short Circuit 200AMP

FIG. 6b



Recloser of the lock-open type installed in the main supply network with Subsidiary lines fuse protected

FIG. 6c



Recloser of the hold closed type installed in the main Supply network with back-up fuse protection. Subsidiary Circuits fuse protected.

FIG. 6d

autorecloser with fuses gives satisfactory result (Fig. 6B). The conventional co-ordinated circuit reclosers are generally 'look open type' (Fig. 6C). The other type which has great prospect in this country is 'hold closed' recloser which operates very rapidly to clear a temporary fault before the fuse can blow and then holds closed when proper fuse clears the fault. This type of recloser is capable of withstanding temporary abnormal current due to pick up of load after shut-down which may be sufficient for 'look open type' recloser to open (Fig. 6D).

Communication: Carrier current telephony on power line for communication has been in use in power system for the past quarter of a century. The success of carrier current communication has introduced its use in telemetering and in control purposes too. Though carrier current now supplies a basic demand very satisfactorily for high voltage network, yet because of the crowding of frequency-spectrum it will have application restricted to feeders, the field of principal transmission will perhaps be invaded by a system of micro-wave. Mobile maintenance units and portable walkie-talke units have become very useful for maintenance work.

Stability & Importance of Network Analyser: In India, where large hydro schemes have to be developed with long transmission line, the problems of system stability should require careful study.

The design of long distance transmission system is greatly influenced by voltage drop and synchronous stability. For all lines above 150 miles for 132 kV and 200 miles for 220 kV for our country should be initially checked for stability of synchronous machines connected at both ends.

Reactance compensation with synchronous condenser or by shunt capacitor has now been frequently adopted in our country as the transmission of vars required by the load and consumed in the inductive plant usually adversely affect the load carrying capacity of line. Reactance compensation with series capacitor seems to be a very useful means of improving system stability. The active length of line in so far as power frequency is concerned is shortened by the insertion of series capacitors. The development of the series capacitor was retarded for a long time in India as well as in other parts of world due to scarcity of long lines. It is still difficult to provide adequate protection for such capacitor against voltages associated with fault currents. Synchronous machines run satisfactorily in parallel as long as they can exchange sufficient power to correct any phase swinging that may take place between them due to any change of load or other disturbances. As regards transient stability it is not the critical angle which counts but the most important factor is critical fault duration curve which must have to be solved with the help of a network analyser.

The use of network analyser is imperative for the design and planning of our power system. It is effectively used for the study of problems associated with Loading, Fault, Stability and High frequency transient. It is a most difficult and strenuous proposition to solve complicated problems analytically without the help of a network analyser. Changes of load, alteration of transformer tappings, modification of reactive control by the application of synchronous condensors, the effect of outages of lines or plant are a few of many investigations that could be carried out in detail. An operating condition is frozen on the analyser set up for each of the conditions of interest and a record is made for voltage and power for each case.

Studies to determine the maximum and minimum currents and voltages under conditions of fault which are essential for the application of circuit breaker and protective devices could however be easily carried out on a simple D. C. network analyser with sufficient accuracy for all practical purposes. But the scope and accuracy of such analyser are limited.

The limits of stable operation under steady condition are determined on A. C. network analyser by increasing the loading in steps thus stretching the network until it reaches the limit of synchronism. In a multi-machine system the power angle relations are complex and the problem of stability is checked by increasing loading in such a way that angles between machines are not widely separated to get out of synchronism. The determination of steady state limit is usually of less importance than that of transient limit i.e. the limiting power that can be transmitted without synchronism being lost when a fault is successfully cleared. The usual procedure is to plot swing curves or angle time curve to determine whether the machines swing back in a steady state following a disturbance.

These curves require to be studied step by step on an A. C. network analyser augmented by necessary analytical calculation to include the effect of inertia of machines as it is not possible to correctly represent inertia and time factor on a static type of A.C. network analyser.

The transient network analyser which is broadly similar to the static type A.C. network analyser but is designed to have sufficient accuracy over a wide range of frequency, is extremely useful to determine level of insulation and to choose over-voltage protective devices for any system and greatly influence the design of circuit breakers and other plants. Normally the design of miniature apparatus to fulfil this function justify a separate installation but recently British E. R. A. has designed an analyser operating at about 1.5 kilo cycles to carry out both functions. This is reasonably accurate for a range from 150 cycles to 10 kilo cyles. This is sufficient for the study of circuit breaker restriking voltage transients and that of lightening by changing the frequency scale. The total number of A.C. network analyser in the world is about 50 of which 4 or 5 are in Britain. In India we have only one. It is highly desirable that we should have a few more analysers of modern types operating at higher frequency.

Prospect

In a review of this nature an attempt is usually made to forecast what the future has in store. Prior

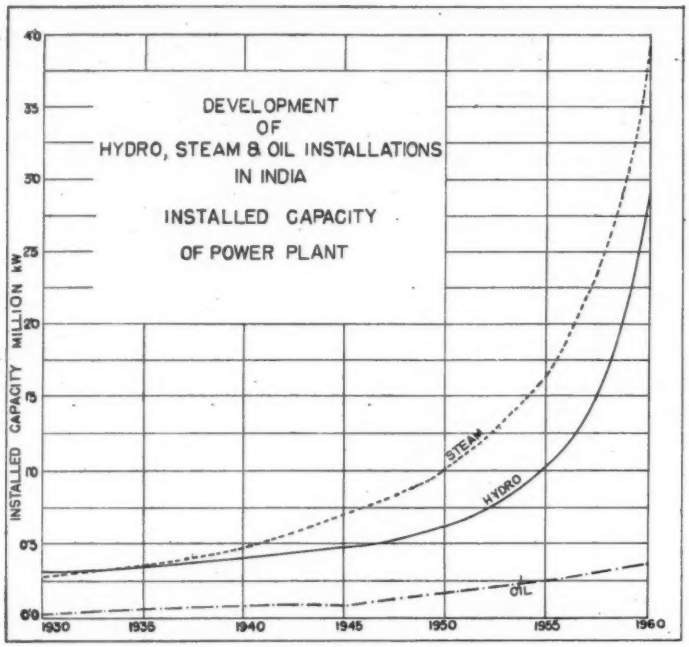


FIG.7

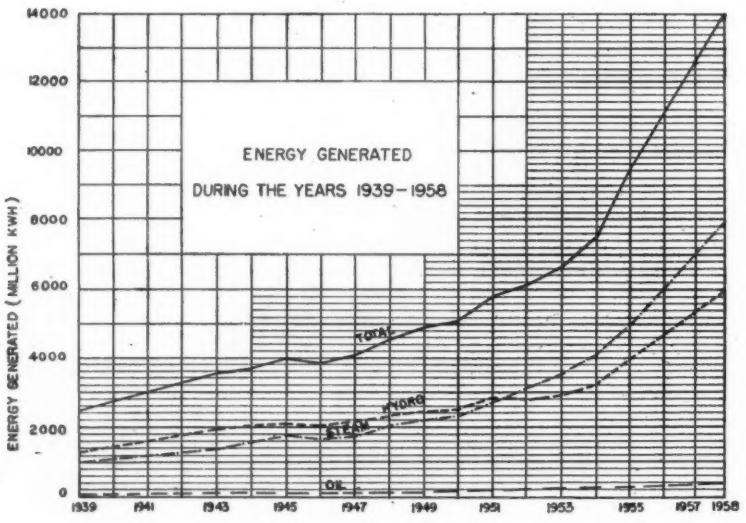


FIG.8

to independence electric power generation was confined only to some remunerative urban and industrial areas. With the initiation of successive Five-Year Plan programmes, the importance of electric power for an all-sided and balanced economic development of the country has been duly recognised.

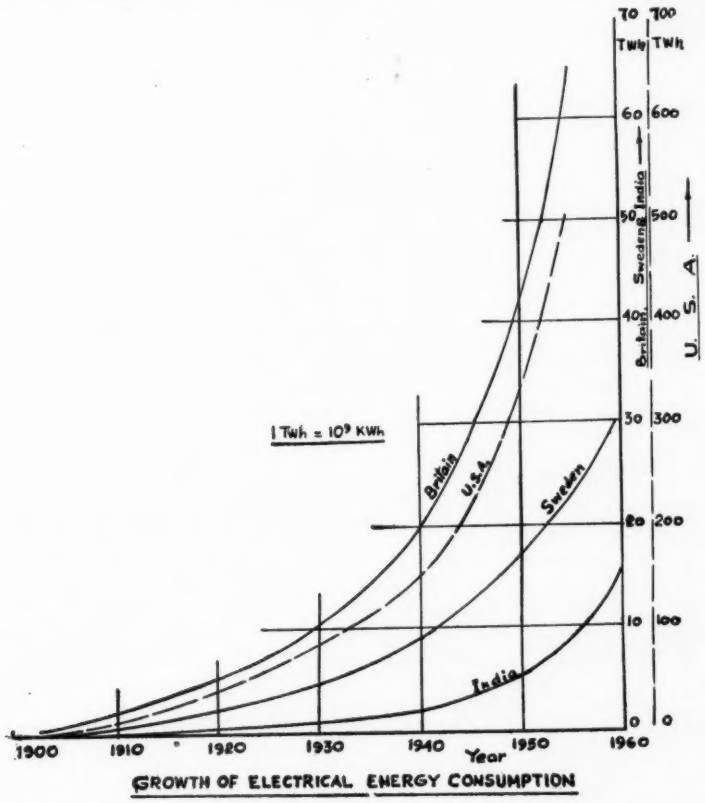
At the beginning of the First Five-Year Plan the total installed generating capacity of power plants in the country was 2.3 million kW. During the First Five-Year Plan period 1.1 million kW plant was added bringing the total installed generating capacity including the installations in the self-generating industries to 3.4 million kW at the end of the First Plan Period. The target under SFYP is to increase the installed capacity by 3.4 million kW bringing the total generating capacity to 6.8 million kW at the of the second Plan period. (Fig. 7 &8).

The growth of power consumption and its pattern

are largely determined by the tempo and pace of industrialization. The most remarkable thing about electricity supply is the way in which load had doubled itself over and over again in periods of time which has seldom been longer than 7 to 8 years in most advanced countries. (Fig. 9). The present rate of gowth of power consumption in our country is of the order of 10 to 12 per cent. But in view of rapid industrialization, the Planning Commission consider it realistic to provide for an annual increase in demand of power at 20% upto the end of third Plan period. The question is how long this increase will be maintained. There is, however, no definite sign of saturation as yet in sight and my opinion, however, is that it is still a long way off. The rate of load doubling every 7 years would mean doubling of the network every seven years which would also mean the facing the problem that in course of next 7 years we have to build as much as has been built over all the years to date. But the lower voltage network will remain substantially unchanged and is made to carry more and more load by introducing injecting points at every decreasing distance. Most of the development that has taken place, therefore, is primarily the development of higher voltage network.

The 132 kV grid which is regarded as a power transmission system in this country as a whole, may have to be regarded as much more a distribution system as time goes on aided by introduction of higher voltage network of which 220 kV is the next prospective voltage for use of transmission system. Indeed the connection of power station direct to 220 kV network will soon be realised and in a decade or so if large generating power stations continue, and I think they will, all important power stations will take very little note of the existence of 132 kV network unless completely automatic generator working from nuclear power make local generation economic. But it is difficult at this stage to foresee anything that could vastly affect the upward trend in the adoption of higher and higher voltage.

So I conclude with the thought that power supply and distribution will continue to grow and expand. Those who are engaged in the field of Power Engineering can rest assured that the future holds much in store to keep them interested. Power Engineering is not the exclusive role of Electrical Engineers. Civil, Mechanical and Electrical Engineers and also the Metallurgists—all will have to act in concert and co-operation to make our to-day's dream a reality of to-morrow.



GROWTH OF ELECTRICAL ENERGY CONSUMPTION

Fig. 9

My friends, permit me to thank you all once again for the honour you have done to me.

References

1. Taylor, E. O. — Power system planning and economics — Generation.
2. Yadava Mohan and Swayambu, S. — Priorities for Long-term Planning for Power.
3. Vij, C. L. and Chandan, C. K. — Regional Planning for Power
4. Lyon, G. — Power system planning and economics — H.V. Network.
5. Datta, M. and Ganguly, R. N. — Nuclear Power Generation.
6. Greeles, F. M. — Electrical Power from Nuclear Reactor.
7. Bhardwaj, D. C. — Thermal Power Stations, Indian Journal of Power & River Valley Development.
8. Newman, V. G. — The use of pumped storage in Electricity Supply — The BEAMA Journal.
9. Brown, F. H. S. and Booth, E. S. — Coal & Oil Fired Power Station — British Electric & Power Convention.
10. Robson, L. S. — The contribution of Turbo-Alternator Manufacturers to Technical Advancement and to National Economy (B.E.P.C.,).
11. Datta, M. — Power line design— Electrical Review, May 51. and May '52.
12. Philip Sporn — Recent and Past Progress in Power Transmission — Electrical Engineering, Oct. '55.
13. Flurschein, C. H. — Transmission Switchgear for 132 KV and High Voltage (B.E.P.C.).
14. Rippon, E. C. — Development in Transformers for 132 KV and Higher Voltage (B.E.P.C.).
15. Cliff, J. S. — Power Station and Distribution Switchgear — B.E.P.C.
16. De Ferranti, S. — Distribution of Transformers — B.E.P.C.
17. Chatterjee, G. P. — Metallurgical Research and Education (Presidential address at I.S.C.A.).
18. Roe, W. E. and Dowing, P. J. — Rural Electrification in Ireland.
19. Datta, M. — Electricity in the Countryside —Indan Journal of Power and River Valley Development.
20. Mandeno — Rural Power Supply especially in Backward Countries.
21. Stowell, P. D. — A review of some aspects of Electricity Distribution (Chairman's Address to the Mersey and N.W. Centre of I.E.E.
22. Seewar P. W.—Civil and Mechanical Engineering Aspect of Hydro Power Development — Water Power, Dec. 1952.
23. Seewar, P. W. — Recent tendencies and present position of hydraulic machinery (Centenary lecture I.M.E.).
24. Pierson, Pollard N. Care — Automatic circuit reclosers I.E.E. proceedings — Dec. 1954.
25. Leyburn and Lackey — Protection of Electrical Power Systems — A critical review of present day practice and recent progress.
26. Goldsborough, S. L. and Hill, A.W.—Relays and Breakers for High speed Simple Pole Tripping and Reclosing—A.I.E.E. Trans 1942.

BUMPER SPECIAL ISSUES OF INDIAN MINING JOURNAL

"COAL INDUSTRY IN INDIA"—carrying 45 Papers by leading authorities read at the symposium on India's Coal Industry organised jointly by the Geological, Mining and Metallurgical Society of India and Indian Mining Journal. The articles provide a valuable and comprehensive survey of the coal industry in India. **Price Rs. 7/8/-**

"COAL WASHING IN INDIA"—carrying 23 Papers read at a symposium on Coal Washing organised by Central Fuel Research Institute. These contributions by experts in the field of fuel research make an almost exhaustive study on a high technical level of all aspects of coal washing in India. **Price Rs. 5/-**

"ECAFE NUMBER" carrying articles on many important aspects of geology and minerals by officers of the Geological Survey of India—published in commemoration of ECAFE meetings on Geological Map and Mineral Resources Development of Asia and the Far East, held in Calcutta from Nov. 4 to 16, 1957. **Price Rs. 5/-**

"MINERAL BENEFICIATION & EXTRACTIVE METALLURGICAL TECHNIQUES"—carrying 57 Papers from eminent scientists and technologists read at a symposium held at the National Metallurgical Laboratory, Jamshedpur, from February 8 to 11, 1957. **Price Rs 15/-**

Place your orders with :

Manager

INDIAN MINING JOURNAL

6/2, MADAN STREET CALCUTTA-13

THE CEMENTATION COMPANY LIMITED

★

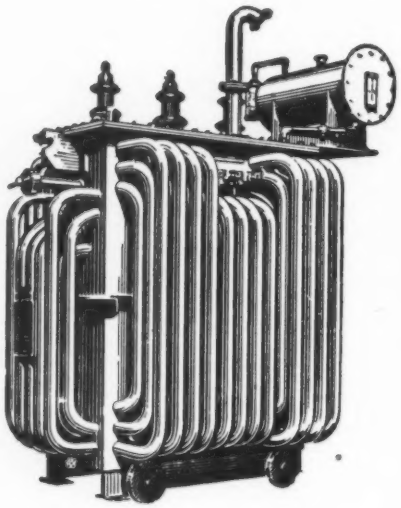
Specialists in:—

- **Drilling**
- **Pressure Grouting**
- **Bored Piling**
- **Guniting**

with over thirty years' experience

★

Steelcrete House, Dinshaw Vachha Road, Bombay
5, McLean Street, Madras
3, Esplanade East, Calcutta



BHARAT

BIJLEE

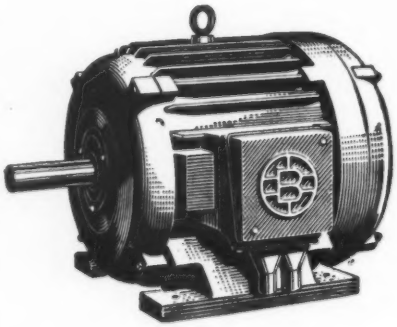
TRANSFORMERS

FOR

ECONOMICAL AND

EFFICIENT *DISTRIBUTION*

OF POWER



ELECTRIC MOTORS

FOR

ECONOMICAL AND

EFFICIENT *UTILIZATION*

OF POWER

IN INDUSTRY & AGRICULTURE

BHARAT BIJLEE LTD.
KING'S CIRCLE, BOMBAY 22.

Power Development in India: Present Position and Prospects

By M. HAYATH AND S. SWAYAMBU
Chairman and Director
Central Water and Power Commission

Planning for power projects is a continuous process and is based on long term objectives. Targets for additional power capacity have to be fixed having regard to the requirements of power for various sectors, such as heavy industries, ore and coal mining, electro-chemical industries, railway electrification etc. During the Second Five Year Plan, emphasis has been laid on the development of industries and mineral resources of the country together with a corresponding expansion in the transport and communication facilities, including railway electification to some extent. Hence the power development programme occupies the next position of importance in the Second Five Year Plan. While the development of industries and mineral resources is in the central sector, power development is one of the major activities of the State Governments and it constitutes approximately one-fourth of the Plan expenditure of the States.

Second Five Year Plan

The Second Five Year Plan as originally formulated provided for an increase of 3.5 million kW in the installed generating capacity of power plants in the country, consisting of 2.9 million kW in the Public Sector, 0.3 million kW in the Private Sector and 0.3 million kW in self-generating industrial establishments. This increase comprises 1.7 million kW capacity to be provided by the spillover schemes of the First Plan and 1.8 million kW to be added by new schemes commencing in the Second Plan. The target of 3.5 million kW is made up of about 2.1 million kW of hydro and 1.4 million kW of thermal power plant. In all, about 44 hydro and steam power generating schemes (both new and extensions to existing stations) were proposed to be undertaken. Of these, 25 are hydro electric schemes and 19 are thermal schemes. Most of the power schemes were programmed to yield benefits during the currency of the Plan. The Plan targets also envisage the construction of adequate transmission lines (35,000 miles of high voltage lines) and the necessary transformer stations and the electrification of about 10,000 villages. A financial outlay of Rs. 427 crores has been provided for schemes included in the Plan. Out of this, Rs. 235 crores are to be spent on generation, Rs. 92 crores on transmission, Rs. 25 crores on distribution in urban areas and small towns, and Rs. 75 crores on rural elctrification. An outlay of Rs. 160 crores is required for schemes continuing from the First Five Year Plan and an additional outlay of Rs. 245 crores is proposed for the schemes to be completed during the Second Plan and Rs. 22 crores for schemes the benefits from which would be derived in the Third Plan. The new power generation schemes undertaken in the Second Plan can be classified as follows:—

Schemes costing	over	Rs. 10 crores	8
do.	do.	between Rs. 5 & 10 crores	5
do.	do.	Rs. 1 & 5 crores	17
do.	do.	less than Rs.1 crore	1

Of the 44 schemes referred to above, Bhakra-Nangal, Damodar Velley, Chambal, Hirakud, Tungabhadra, Rihand and Koyna are centrally financed projects.

Development of Power during the First Plan

At the beginning of the First Five Year Plan, the total installed capacity of power generating plants in the country was 2.3 million kW of which 1.7 million kW was in public utilities and 0.6 million kW in industrial establishments generating their own power. The target for the First Plan was fixed at 1.3 million kW, of which 1.1 million kW was to be provided by the public sector and 0.2 million kW by private electricity supply companies. The total provision for expenditure on power projects included in the First Plan amounted to Rs. 260 crores including the proportionate costs on power from multipurpose projects. In major river valley projects, like Bhakra Nangal, Damodar Valley, Hirakud, Chambal, Koyna, Rihand etc. where extensive civil works were involved, some delay was experienced during the initial stages in completing the investigations, in revising the scope of the projects and in setting up the necessary organisation for their execution. In addition, as the country had to depend largely on imported machinery and equipment for generation and transmission of power, delays occurred due to protracted deliveries from

foreign manufacturers. Difficulties in the procurement of key materials like steel and cement were also experienced to some extent. Despite the difficulties, the public sector accomplished 0.8 million kW and the private sector 0.2 million kW. No target was set for power plants in industrial establishments A number of them have closed down their less efficient generating plants and changed over to bulk supply from public utility grid systems and there was a net increase of about 0.1 million kW in the power plant capacity of industrial establishments bringing the total capacity to 0.7 million kW at the end of the First Plan.

A number of projects, which were commenced during the First Plan have either been completed or are at present in different stages of construction and so far, during the Second Plan about 580 MW of generating capacity has been added by the completion of these schemes. The major multipurpose projects like Chambal, Rihand, Koyna and Bhakra-Nangal will be completed for the greater part in the latter part of Second Plan. A brief review of progress in the various States is given below:—

Andhra: Under the Machkund hydro-electric scheme, which is a joint scheme of the Andhra and Orissa States two units each of 17,000 kW were commissioned during the First Plan period and a third similar unit was commissioned in June, 1956. The installation of three more units of 21,250 kW each is in hand and is expected to be completed by 1959. The first stage of Tungabhadra Project comprising the installation of 2 units of 9,000 kW each at the dam and canal power houses, has been completed and a further addition of 4 units is also included in the Second Plan. A new thermal station of 30 MW capacity has also been proposed under the Tungabhadra-Nellore hydro-thermal scheme. In the Ramagundam thermal scheme all the 3 sets of 12,500 kW were commissioned in 1957. Three units of 5,000 kW each were commissioned during the First Plan period at the Nizamsagar hydroelectric station. Investigations on the Sileru hydroelectric project have been completed and the project report for the same has been prepared. It is proposed to commence work on this scheme, which will initially have an installed capacity of 2-60,000 kW units. The Devanoor hydro-electric scheme under which 2 units of 13,500 kW each are proposed to be installed, is under investigation.

Assam: The Umtru hydro-electric scheme undertaken during the First Plan was commissioned in July'57 with an installed capacity of 8,400 kW. During the Second Five Year Plan a thermal station of 6,000 kW may be installed at Umtyngar and about 1,700 kW of plant is proposed to be added by small schemes under the programme of rural electrification.

Bihar: In addition to making arrangements for the construction of diesel power stations in areas far away from grid transmission lines, particularly in North Bihar, the State Electricity Board have made extensive arrangements for distribution of bulk power purchased from the Damodar Valley Corporation. During the Second Plan it is also proposed to set up a thermal power station of 30,000 kW at Barauni for supply to North Bihar and to the oil refinery proposed to be set up there.

Damodar Valley Corporation : Three sets of 50,000 kW each were commissioned during the First Plan period at Bokaro thermal power station. The station is being extended by the addition of one more 75,000 kW generating set. Two sets of 2,000 kW each were commissioned during the First Plan at Tiliaya hydro-electric power station. At Maithon hydro-electric station, one set of 20,000 kW was commissioned in 1957 while the other 20,000 kW unit was commissioned in May 1958. Work is almost complete on the third unit. A new thermal station of 150,000 kW is at present under construction at Durgapur and it is expected to be completed by the middle of 1959. The Panchet Hill hydro electric project (40,000 kW) is also expected to be completed in 1959. To overcome the acute power shortage in the region, as also to meet the demands of railway main line track electrification and the new industries being set up in the region, a new power station of 125,000 kW capacity at Dugda has recently been sanctioned and it is proposed to be commissioned during the currency of of the Plan.

Bombay: Koyna Hydro-Electric Scheme: Civil engineering works on the first stage of Koyna hydro-electric project where 4 units of 60,000 kW each will be installed, are in full swing. Orders have been placed for most of the equipment and the first two units are expected to be commissioned in 1961. The Utran Steam Power Station in South Gujerat is being extended by the addition of 3 units of 15,000 kW each expected to be commissioned by the end of 1958. The thermal power station under construction at Kandla Port with two units of 3,000 kW each is also expected to be completed before the end of the year. Work is progressing on the extension of Khaperkheda steam power station (30,000 kW) and on the installation of a new power station of 30,000 kW at Akola. These two stations are expected to be completed by 1960-61. Construction of several small size thermal stations has been taken up in Saurashtra region. The thermal station at Porbandar (15,000 kW) and at Sikka (8,000 kW) is in progress while 3,000 kW of diesel capacity has been added at Rajkot.

Jammu & Kashmir: Under the Sind Valley hydro electric scheme 2 sets of 3,000 kW were commissioned at Ganderbal power station and work is in progress at this station as well as at the Mohara power station for the extension of these by the addition of 2 units each of 4,500 kW. These are expected to be completed by 1960-61.

Kerala: During the First Plan, 4 sets of 12,000 kW each were commissioned under the Sengulam hydro-electric scheme. At Poringalkuthu hydroelectric station, 3 units of 8,000 kW were commissioned during 1957, and a fourth unit of a smiliar capacity is expected to be added shortly. Equipment is being received for the Neriamangalam power station comprising 3 units of 15,000 kW each and the station is expected to be in operation in 1959. Civil works are in progress in respect of Panniar hydro-electric scheme under which 2 units of 15,000 kW each will be installed.

Madhya Pradesh: The works under the first stage of Chambal hydro-electric project, a joint enterprise of Madhya Pradesh and Rajasthan States, are progressing well and 3 units of 23,000 kW each will be commissioned by 1960-61. Orders for the fourth set are also likely to be placed shortly. Work on the Korba thermal station (90,000 kW) and 132 kV transmission line from Korba to Bhilai for supply of power to the steel plant, has made good progress and the station is sheduled to be partly commissioned in 1958-59. Among the other schemes in the Second Plan, is a 60,000 kW thermal power station at Birsinghpur which is proposed in place of Katni (20 mW) and Satna-Burhar (20 mW), originally included in the Second Plan.

Madras: Out of the 3 stages of Madras Plant extension scheme, the first two stages with an installed capacity of 30,000 kW were completed during the First Plan period, while the third stage of 30,000 kW has been completed in May, 1958. The Periyar hydro-electric scheme with an installed capacity of $3 \times 35{,}000$ kW is in an advanced stage of construction and one unit was recently commissioned and the second unit is expected to go into operation in the next few months. The Kundah hydro-electric project (180,000 kW) which is under construction with the assistance of the Canadian Government under the Colombo Plan, is fast progressing. The Plant and equipment are being received at site and the civil engineering works are in full swing. The scheme is expected to be completed by 1960-61.

Mysore: The additions of 72,000 kW to the Mahatma Gandhi hydro-electric scheme were completed in 1952. With all the 3 power stations, Sivasamudram, Shimsha and Jog fully loaded, the State is passing through a critical power shortage situation. Three new power development schemes are included in the Second Plan. Most of the generating plant and equipment for the 2 units of 9,000 kW each for the Munirabad power station on the left bank of Tungabhadra has been received at site and the station is expected to be completed by 1960-61. Work is also expected to be completed on the Bhadra project (33,200 kW) by 1961. The most important scheme which will bring substantial and long term benefits to the State is the Sharavathy Valley Power Project. Under this scheme, 2 units of 89,100 kW each are proposed to be installed initially, progressively increasing to a total installed capacity of 891,000 kW. Civil works on this project, which has been given a high priority among the non-core projects, are in progress.

Orissa: The first stage of Hirakhud dam project comprising an installed capacity of 123,000 kW at the main dam along with associated transmission lines has been completed. Work is in progress on the second stage of development consisting of the construction of a power station with 3 units of 24,000 kW each at Chiplima power station and an additional unit of 37,500 kW at the main dam. For the distribution of Machkund and Hirakud power, the State Electricity Dept. is busy with construction of transmission and distribution lines in the various parts of the State.

Punjab: Two units of 24,000 kW at Ganguwal power station were commissioned during the First Five Year Plan and two units of 24,000 kW each have been commissioned at Kotla during June-July-1956. Orders have been placed for an additional unit of 29,000 kW each for the above 2 stations. Five sets of 90,000 kW each at the Bhakra dam will be commissioned by 1960-61. Power is being supplied from Punjab to parts of Jammu & Kashmir add Himachal Pradesh.

Rajasthan. Rajasthan will get 50% share of power output from Chambal project and 15.22% from Bhakra-Nangal project. The construction of transmission lines and substations for utilising the above power is in hand and it is expected that the Bhakra Nangal supply will be available by 1960 and the Chambal supply by 1961. Additions of 5,000 kW at Jaipur and 6,000 kW at Jodhpur, where during the First Plan 7,500 kW and 1,000 kW respectively were added, are also taking place under thermal power stations schemes taken up during the First Plan. An additional, of 8,000 kW of thermal power, plant will be made at Kotah, Alwar and Bharatpur.

Uttar Pradesh: The Sharda hydro-electric scheme with an installed capacity of 41,400 kW was commissioned by July, 1956. Pathri and Mohammedpur stations with 20,000 kW and 9,300 kW installed capacities respectively, were commissioned during the First Plan. Construction of thermal power stations at Gorakhpur, Mau, Sohwal and Mainpuri with an installed capacity of 10,000 kW each, have been completed for purposes of providing power to tubewells. Work on additional generating units of 5,000 kW at each of the first 3 stations is in an advanced stage of erection. At Kanpur, a 15,000 kW set has been added during the First Plan and one more 15,000 kW set is expected to be commissioned by the end of this year. Orders have been placed for 2 units of 30,000 kW each for the Harduaganj thermal station. Equipment for the Rihand Dam has started arriving and two units are expected to be commissioned there by 1960-61. Preliminary investigation on the second stage of Yamuna (150,000 kW) and Ramganga (75,000 kW) are in progress.

West Bengal: Mayurakshi hydro-electric scheme (4,000 kW) continuing from the First Five Year Plan was completed during 1956-57, the Jaldhaka hydro-electric scheme in the northern parts of the State is in the planning and design stage. Bulk power is being purchased by West Bengal from the Damodar Valley Corporation and arrangements have been made for its distribution.

Delhi: During the First Plan, 2 sets of 10,000 kW each were added at the main generating station at Delhi. Bulk power of 20,00 kW is being received from Bhakra-Nangal system. Diesel plant of 6,000 kW has been added in April, 1958 and work is in progress on the installation of additional 14,000 kW diesel plant and 4,000 kW steam plant. A 30,000 kW steam station is expected to be commissioned by 1961 under the TCM Aid Programme.

Private & Industrial Sector

In the private sector, the Tata Power Co.

have commissioned 2-50,000 kW steam turbo sets at Trombay and a third set is expected to be in operation during the Plan. Generating sets of 4,000 kW were commissioned at Allahabad, Agra and Banaras during the first two years of the Plan. Two turbo sets each of 4,000 kW are expected to be commissioned at Bhavnagar during 1958-59 and one set of 15,000 kW at Ahmedabad during the current year. In the industrial sector, construction of 60,000 kW thermal stations at Durgapur as a part of the Durgapur Coke Oven Plant is in progress and is expected to be completed during 1958-59. Steam power stations of 15,000 kW, 25,000 kW and 75,000 kW are under construction at Durgapur, Bhilai and Rourkela steel plants respectively. Indian Iron & Steel Co, will and 20,000 kW thermal plant. A 250 MW station is projected for the Neyveli lignite scheme in South India and part of this plant is likely to be commissioned during the Second Plan period.

Rural Electrification

Rural electrification has been making good progress. From the inception of the Plan up to July, 1958, about 6615 villages have already been electrified. Rural electrification programme is also being aided under the Colombo Plan and TCM Aid schemes under which diesel generating sets and other equipment have been made avilable. With the improvements of the Electricity Supply standards for the rural areas and utilisation of more and more indigenous equipment as well as standardisation of materials and construction practices, it is expected that the target of 10,000 villages will be far exceeded and about 14,244 villages will be electrified during the Plan. Madras, Punjab and Kerala have been leading in the implementation of rural electrification schemes and these above States are responsible for more than half of the target.

Impact of Shortage of Foreign Exchange

The power development programme of the Second Five Year Plan has undergone considerable changes from time to time due to the various reasons. At the time of formulation of the Plan most of the schemes were tentatively included subject to their being found technically and economically feasible and these had to undergo strict scrutiny by the Technical Advisory Committee on Irrigation and Power Projects. Some schemes had to be modified on account of States reorganisation. In some cases modifications were necessitated to enable regional power development. In some regions, the demands from the industries and other essential loads have grown so rapidly that it has been found necessary to provide additional capacity or to modify the scope of the projects already included.

The most important factor which has, however, significantly altered the scope of the Plan has been the paucity of foreign exchange. Due to the difficult foreign exchange position, the power schemes have been divided into four categories depending upon their importance and bearing on other essential sections of the Plan, such as heavy industries, transport, etc. Projects which are intended to supply power to steel plants, coal production and for augmenting railway transport capacity have been included in the core of the plan. Such schemes are Korba, Khaperkheda Akola Extensions, Hirakud II Stage, Lakkavalli (Bhadra) Project, Transmission and distribution schemes for utilisation of power on completion of the projects in progress, Bhakra-Nangal, Chambal, Rihand, Tungabhadra (Left Bank), Neriamangalam, Thermal Stations in Saurashtra, Ganderbal and Mohara Power House.

Schemes which are nearing completion and for which most of the foreign exchange required has been committed, come under the second category. Such schemes are Machkund, Tungabhadra, Kandla, South Gujerat, Grid extensions, Poringalkuthu, Madras Plant Extensions, Periyar, Hirakud I Stage, Projects in Mau, Sohwal, Gorakhpur, Mainpuri, Ramagundam, Allahabad and Thermal Station at the Coke Oven plants at Durgapur.

The third place has been given to schemes which have already been assured of external assistance. These are Umtru, Mayurakshi, Development of thermal stations in Rajasthan, DVC projects, Koyna, Kundah, Delhi thermal extensions, Trombay, Neyveli and the I. I. S. C. C. thermal station.

The rest of the projects have termed non-core projects. Ahmedabad, Harduaganj and Barauni thermal stations and Sharavathy and Panniar hydroelectric projects are being regarded as of highest prority among the non-core schemes. The projects under the first three categories are likely to be completed according to schedule. Efforts are also being continuously made to get some allocation of foreign exchange for non-core projects so that work on the schemes may continue and there is adequate spillover benefits of continuing schemes in the third Plan.

Future planning and prospects.

According to the load survey made by CWPC (PW) the load demand in 1965-66 will be of the order of 8.2 million kW. A generating capacity of approximately 12.3 million kW will be required to meet this demand. The installed capacity at the end of the Second Plan is expected to be 6.4 million kW, thus necessitating an addion of approximately 6 million kW in the Third Plan period. The continuing hydro and thermal schemes of the Second Five Year Plan will yield about 2 million kW and plans will have, therefore, to be made for an additional 4 million kW. Major portion of this additional demand will be met by extending the existing power stations and installing new hydro electric stations. As far as possible thermal generating stations are proposed to be located near pitheads or in areas where firming up or augmenting of hydro capacity is needed. For the areas deficit in hydro resources and are situated away from collieries, a start is proposed to be made with the installation of nuclear power plants. Some of the major thermal and hydro schemes which are likely to be investigated for inclusion in the Third Five Year Plan are given below.

	Hydro	*mW*	*Thermal*	*mW*
Andhra	Upper Sileru	120	Kottagudam (Singareni collieries)	90
	Nagarjunasagar	75		
	Srisailam			
Assam	Umtru extension	5	Umtyngar extension	6
	Umia Barapani	24	Nahar-Katya (Natural Gas)	9
West Bengal	Jaldhaka	17	West Bengal &D.V.C. area)	600
	Balasun	5		
	Tista	300		
Bihar	South Koel	300	Barauni Extension.	30
	Subernrekha	66	Subernrekha	200
	Sone	70	Thermal & South Koranpura	
	Sankh Valley	150		
	Gandak (1st stage)	49		
	Kosi	23		
Bombay	Koyna IInd Stage.	240	Bhusawal-Akola.	90
	Koyna Tail race	60		
	Ukai	160		
	Purna	15		
	Bandardara-Randha	150		
	Banda river scheme	50		
	Pench Valley (MP)	70		
Jammu & Kashmir	Salal	60		
	Lidder Valley	10		
Kerala	Poringalkuthu (right bank)			
	Pambayar-Kakkiyar IInd Stage.			
	Payankuthy & Edamala			
	Silent valley.			
	Kultiyadi or Oorakuzhy scheme.			
	Panamaram and Mananthodi schemes.			
Madhya Pradesh	Hasdeo	62.5	Korba extension	150
	Tons	90	Satpura	150
	Upper Wain gauge	20	Chandni	10
	Sitarewa	20		
	Tawa	20		
	Sindh	25		
Madras	Periyar	35		
	Kundha 3rd & 4th Stage	55		
	Mettur Tunnel	200		
	Kumbhar (Amaravati)	45		
	Polar Porandlar	20		
	Megadattu	52		
	Hogenkal	18		
	Pambiar & Alladi	120		
	Sholayar-Parambikulam-Aliyar.			
Mysore	Sharavathy Project (extension by 4 sets)	356.4		
	Linganmakki Dam	60		
	Shimsa Seasonal	178.2		
	Barapole	74		
	Tungabhadra Canal P. S.	40		
Orissa	Bhimkund (on Baitarni river)	200	Jharsuguda or Talcher	60
	Rengali (on upper Brahmani)	160		
Punjab	Bhakra Right Bank	360		
	Jogindernagar Extension.	10		
Rajasthan	Ranapartap Sagar	112	Thermal Station at Bikaner.	
	Kotah	48		
Uttar Pradesh	Yamuna	150	Muradnagar	90
	Ladhia	150	Shahjahanpur	60
	Pancheshwar		Kanpur	60
	Dhukwan	12		
	Laha	11		
	Orchha	33		
Delhi			Thermal Station.	125

In order to have a rationalised power development programme, it is important to consider the problem on a long term basis for a period of at lest 20 to 25 years and then to fit in the short-term system development programmes in the over-all master plan. Taking into consideration the developing economy of the underdeveloped countries limited by the financial resources available, the load demands and the installed capacities required over the period 1965-66 to 1985-86 are given below:

Year	*Load demand MW*	*Installed plant capacity- MW*
1965-66	8.2	12.3
1970-71	12.6	18.0
1975-76	19.2	26.5
1976-81	27.0	37.2
1985-86	38.0	50.7

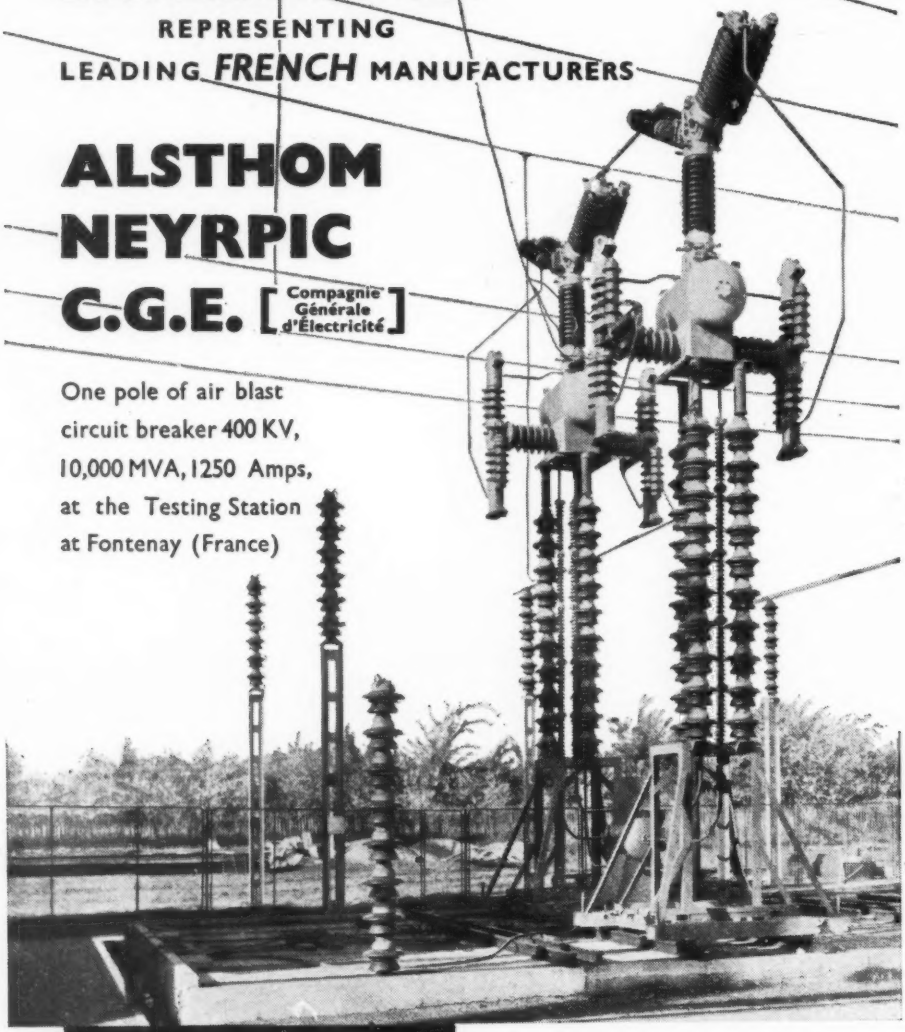
[*Continued on page* 34

BATLIBOI & CO.

REPRESENTING
LEADING *FRENCH* MANUFACTURERS

ALSTHOM
NEYRPIC
C.G.E. [Compagnie Générale d'Électricité]

One pole of air blast circuit breaker 400 KV, 10,000 MVA, 1250 Amps, at the Testing Station at Fontenay (France)



BATLIBOI & COMPANY
Proprietors:
BHOGILAL LEHERCHAND
PRIVATE LIMITED

Head Office: Forbes Street, Fort, Bombay
Branches: Madras — Calcutta — Delhi
Ahmedabad — Coimbatore — Kanpur
Vijayawada — Secunderabad (Dn)
Associates in Bangalore

SISTA'S-B-122

Power Requirements of India during the Second, Third & Fourth Plan Periods

By S. S. KUMAR and A. SHANKARAN
Member (Utilisation) and Director
Central Water and Power Commission

It has been agreed on all counts that the extent of utilization of electric power, is an index of the economic prosperity of a country as well as of the standard of living of its people. Electricity is indispensable for augmenting the overall productivity of the country through rapid industrial development. The production of electric power in abundance and at economical cost, calls for the planning and development of power projects on a rational basis to ensure the most effective and balanced utilization of the nation's power resources. To derive the optimum benefits from the co-ordinated operation of power generating schemes and to avoid undue blocking of capital in power generation that may result by planning too much in advance or in the other extreme too little to cater for demands, it is necessary to correlate power production with its utilization. This has been appreciated by the planners and our Five Year Plans aim at making power available sufficiently ahead of demand with a view to reduce the interval between power availability and its utilization in order to achieve a rational development of power consistent with economic planning. It is in this context that a power load survey in an area over a period of years is necessary to determine as far as practicable the immediate and potential demands of power under various categories of load. Further such a load survey would also provide valuable data in locating new industries.

Any power system properly designed has to be flexible so that it not only caters for immediate demands economically but also should be capable of extensions from time to time to meet the long term requirements of the region. As the distribution of natural resources of power and the scope for its utilization do not conform to the political boundaries of individual states, it was considered by Government of India to have a systematic power load survey carried out on a regional basis and co-ordinate the same for the whole country. Accordingly the Central Water and Power Commission was entrusted with this work in April, 1955. In order to have a quick appraisal of the likely power demand and its availability in the country for the next fifteen years, the Commission was required to carry out a preliminary load assessment of all the States, basing it on the data readily available with the State authorities concerned, the Central Ministries and to supplement the same by conducting sample surveys in the field. This survey has since been completed and report is under publication.

For presenting a more comprehensive picture of the power requirements and allied problems of the country detailed studies requiring intensive investigations in the field are now being conducted and these are likely to the take another three years or so to be completed.

Estimating Power Requirements

There are basically two methods (*i*) Statistical (*ii*) Field Survey — for estimating future demands of an area. For purposes of assessing immediate power demands the field survey method is generally adopted. In this method the load survey or visits to each and every town and village of the area to be surveyed and records the present and future needs of the community. Having thus obtained a picture of the present condition along with the knowledge of the future requirements, he tries to evolve the pattern of load growth by taking into account all the probable influences and changes that are likely to take place. The Statistical method is generally used for assessing future requirements and involves the study of the data collected from the past records and its extrapolation into the future. It is of the greatest value in gauging broad features and trends in the absence of any unforeseen developments such as establishment of major industries etc. which may alter the future load pattern altogether. Best results are obtained by a combination of these two methods in determining future power requirements of an area under the various categories of load. While determining the growth of load under each category the past trends are also to be studied and due weightage given to the present trends.

In large and heavy industries such as electro-chemical or electro-metallurgical, a special study has to be

made, as such loads in a region cannot normally be projected into the future.

Classification of Loads

The forecast of power demand requires considerable study of past trends, as also knowledge of the present position and a mass of information about future plans in all walks of life. In collecting data a systematic method has to be adopted to avoid repetition or omission and to arrive at the correct simultaneous demands, each class of load is studied separately.

For purposes of standardisation the Central Water and Power Commission has classified various loads under the following main categories.

(*a*) Domestic & Commerical lighting & power.

(*b*) Street (Public) lighting.

(*c*) Industrial load subdivided as follows:

(*i*) Small scale industries (upto 25 BHP)
(*ii*) Medium Industries (25-1000 BHP)
(*iii*) Large Industries (100 to 500 BHP)
(*iv*) Heavy Industries (above 500 BHP).

(*d*) Irrigation.

(*e*) Railway track electrification.

(*f*) Water supply & Drainage.

Pattern of Power Consumption

The history of power development in India has been slow and chequered. Most of the electric utilities in the country were privately owned to serve the needs of urban population in large towns and cities and their plans of power expansion were carried out only on a short term basis with a view to meeting the immediate demands of a paying character. Rural areas were altogether neglected on account of the rural schemes not being self supporting. Further, the development of industrial production did not receive the attention it deserved from the Government of the day with the result that the growth of power development was slow compared to that of other industrially advanced countries.

The total generating capacity of electric utilities in 1939 was only 1.07 million kW with an aggregate maximum demand of 0.58 million kW. By the end of 1950, that is at the beginning of the First Plan, the installed generating capacity in the country was 2.3 million kW of which 0.6 million kW was owned by industrial establishments for their own use and the corresponding demand resulting therefrom, was 1.6 million kW. The progress of power development was largely hampered by the Second World War; but after Independence and with the initiation of Five Year Plans, the importance of electric power schemes as a first step towards the industrial and economic development of the country was well recognised and a number of major power projects were launched during the First Plan. In fact schemes costing Rs. 292 crores were completed during the period 1950/51 to 1955/56 and the total installed capacity was increased to 3.4 million kW to cater for an aggregate demand of 2.14 million kW. The Second Five Year Plan provides for a further outlay of Rs. 469 crores on power schemes to achieve a target of 6.9 million kW of total installed generating capacity, in order to meet the present and anticipated demands of various categories of load at the end of this period.

The figures below show the distribution of electrical energy in 1956 as between various categories of consumers.

Class of utilisation.	*kWh sold million.*	*Percentage of total sales.*
1. Domestic & Commercial lighting & power.	1479.97	18.5
2. Street (public) lighting	117.77	1.5
3. Industrial power.	5323.42	66.9
4. Irrigation.	316.18	4.0
5. Railway track electrification	404.93	5.1
6. Water supply & Drainage.	317.08	4.0
	7959.35	100.0

Generally speaking the above has been the pattern of consumption during the last several years and it is likely that this pattern may not change substantially in the next few years, though the consumption of electrical energy by industries will be predominantly greater than that of other types of consumers. This is of course to be rightly expected as power is an essential requisite for industrial expansion.

Forecast of Power Requirements at the end of Second, Third and Fourth Plan Periods

The results of the recent preliminary load survey carried out on a national basis giving the estimated demands for the various categories of load at the end of Second, Third & Fourth Plan periods as compared to the actuals for 1955/56 are brought out in the following table:—

Category of load.	*Demand at end of 1955/56.*	*Esttimated demand by end of*		
		1960/61.	1965/66.	1970/71.
i. Domestic & Commercial lighting & small power	MW 527	MW 832	MW 1213	MW 1754
ii. Street (public) lighting	37	56	83	118
iii. Industries	1677	3914	7037	10017
(*a*) Metallurgical				
i. Iron & Steel	123	419	1021	1500
ii. Ferromanganese	—	78	137	200
iii. Aluminium	24	63	209	345
(*b*) Textile				
iv. Cotton	329	417	504	582
v. Rayon	13	53	98	155
vi. Jute	136	165	204	239
vii. Woollen	12	16	16	16

Category of load.	Demand at end of 1955/56	Estimated demand by end of		
		1960/61.	1965/66.	1970/71.
(c) Chemical & Allied Industries.				
viii. Nitrogeneous Fertilizer	49	157	570	800
ix. Phosphatic Fertilizer	—	21	108	183
x. Heavy chemicals, caustic soda, Soda ash.	26	165	285	435
xi. Paper & Paper Board	53	122	163	228
xii. Cement.	87	184	330	465
(d) Engineering Industries				
xiii. Elect. Engineering.	4	18	28	37
xiv. Industrial machinery manufacture.	4	39	66	74
(e) Sugar manufacture	18	38	52	63
f. All other industries including small and medium.	799	1956	3246	4695
IV. *Irrigation.*	127	380	627	943
V. *Water Works*	127	128	178	244
VI. *Railway track electrification.*	59	212	524	896
VII. *Miscellaneous bulk supplies (for Railways, M. E. S. etc)*	97	136	187	239
Aggregate of simultaneous demands on utilities and non-utilities of all States in the country.	2136	4623	8190	11801

The above estimates of demands are based on the various development programmes envisaged in the Second Plan which aims at rapid industrialization of the country with emphasis on the development of basic and heavy industries both in the public and private sectors. The power requirements for the Third and Fourth Plan periods have been estimated on the current trends of industrial development, in the absence of any authentic data with regard to new industrial projects that may come about during these periods.

The sudden rise in power demand in India in recent years, is due to various factors, such as meeting the pent-up demands of the Second World War period and the very accelerated tempo of activities since the attainment of Independence, particularly in the field of industrialisation, lift irrigation and Railway Track Electrification. Above all, the imagination of the people has been caught and they are as keen as the Government to raise their earning capacity and standard of living. As soon as electric power reaches the remote corners, small size industries will spring up in villages. In towns and cities there is an unprecedented urge for setting up large-size industries. The States are vying with one another for the allotment of heavy industries. There has been 60% rise in industrial production during the first ten years of Independence viz. from 1947 to 1957 and an overall increase of 7 to 8 percent has been achieved in the last two to three years. The per capita income increased from Rs. 255/- in 1951 to 281/- in 1956. It is expected that with further prosperity as a sequel to industrialisation, the per capita income may rise to Rs. 330/- by 1960/61 and to about Rs. 400/- by 1965/66 as estimated by the Planning Commission.

Trend of Load Growth

The trend of growth of different categories of load is discussed briefly below:—

Domestic & Commercial Lighting and Power

The growth of demand from this category of load is dependent on the rise in the standard of living of the people as also on the extent of electrification in the country. Statistics show that approximately 85% of the population live in rural areas. As per 1951 census there were 1441 localities with a population above 10,000 and about 560,000 localities with population below 10,000. Out of these 900 and 8,404 localities respectively had been electrified by the end of First Five Year Plan period. The Second Plan programme of the States provides for extension of electric service to about 14,100 additional localities including groups of hamlets, thus bringing the total to about 23,400 as against 18,000 provided in the Second Plan. This programme of electrification also covers all the towns having a population of 10,000 and above. Nevertheless it will be apparent what a tremendous task lies ahead of us in bringing the benefits of electricity to our people.

Street (Public) Lighting

The growth of this category of load in a locality depends on the length of streets and shopping centres as well as on the ability of the local administration to pay for this service. The results of the recent survey indicate that the growth of demand of public lighting generally bears relationship to the growth of domestic and commercial lighting. The demand for public lighting forms about 7% of the demand for domestic and commerical lighting on an all India basis With the rise in the standard of living better lighting of roads, streets and public places would be necessary.

Industries

This category of load is by far the most outstanding not only from the point of view of power consumption but also of investment and employment opportunities. Industrial development is the key-note of the Second Five Year Plan. As against a total investment of about Rs. 260 crores now estimated to have been incurred on industrial expansion in the public and private sectors during the First Plan, a sum of Rs. 1189 crores i.e. about 4.5 times the former amount is earmarked for organised industries in the Second Five Year Plan. Besides development of large & heavy industries to meet the basic requirements of the country due emphasis has been laid on encouraging the growth of small and village industries. This would not only help to achieve a balanced national economy in the rural areas but would also provide greater scope for employment and promote decentralised industrial sectors.

For purposes of load estimates as already mentioned large and heavy industries have been classified as those

with a connected load of 101 to 500 HP and above 500 HP respectively. As such the word 'Industry' as generally implied and understood refers to these two classes. A wide variation in regard to manufacturing process, capital investment and power requirements exist in the case of these industries. A few of selected major industries that require large blocks of power are considered in the following paragraphs.

Iron & Steel

The consumption of steel is an index of industrial development of the country and is directly related to the electrical energy generated. The steel expansion programme for the Second Plan, which involves an outlay of Rs. 462 crores provides for increasing the production capacity from 1.63 million tons in 1955/56 to 6 million tons by the end of 1960/61. This is to be achieved by increasing M/s. Tata's capacity from 1 million to 2 million tons. M/s. Iirsco's from 0.57 to one million, and M/s. Mysore Ion & Steel Works from 0.035 to 0.1 million tons, in the private sector and by the setting up in the public sector of three new plants, one each at Rourkela, Bhilai and Durgapur which would initially produce one million tons of steel ingots at each plant. It is planned to increase the production capacity to 15 million tons by the end of Third Plan and to 22.5 million tons during the Fourth Plan. The basis of power requirement for this industry is of the order of 70 MW for a one million ton plant.

Ferromanganese

This is processed from manganese ore and is used in the manufacture of steel. No target of production was fixed for the First Plan. The consumption of ferromanganese is directly related to the production of steel in the ratio 1:100. Therefore for an estimated production of six million tons of steel by the end of Second Plan the requirement of ferromanganese is estimated to increase to 60,000 tons per annum to meet internal consumption. Besides efforts are being made to step up production, for export purposes also—considering its capacity to earn foreign exchange. The total capacity licenced for production by the electrical process by the end of 1957 was 123,800 tons per annum. The target set by the Planning Commission for the Second Plan is 160,000 tons per annum of production capacity. Basing the requiremnt of ferromanganese for internal consumption on the indigenous production of steel the country would require 150,000 tons by 1965/66 and 225,000 tons by 1970/71. On the assumption that the exports may reach 125,000 tons by the end of 1965/66 and 150,000 tons by the end of 1970/71, the total required production of ferromanganese will be 276,000 and 400,000 tons per annum requiring electric power to the extent of 137 MW and 200 MW respectively.

Aluminium

Amongst the non-ferrous metals, aluminium great demand. Due to its versatile uses for domestic and industrial purposes, especially for power transmission in the form of A. C. S. R. and aluminium conductors, its demand is rapidly rising, specially because copper is in short supply. The First Plan envisaged expansion of the capacity for aluminium ingots from a total of 4,000 tons in 1950/51 to 20,000 tons by January, 1956, through (*i*) the expansion of the two existing plants to 5,000 tons each and (*ii*) installation of a new factory at Hirakud with a smelter of 10,000 tons annual capacity. As the installation of the Hirakud Factory had been delayed for various reasons, the production during 1955/56 in the country was only 7,340 tons. During the Second Plan period not only the plant at Hirakud will commence production, but a new smelter of 10,000 tons capacity is proposed to be established either at Mettur in Madras State or in Rihand area of U. P. Although no final decision has yet been taken, it is likely that the plant in Rihand area may be established during the Second Plan whereas the other unit may come in during the Third Plan period. According to the targets indicated in the plan, the total installed capacity for aluminium by 1960/61, would be 30,000 tons and the estimated production 25,000 tons. Although final plans for location of new units for production of aluminium, are not yet known, considering the increased use of this metal in various industries, it is likely that the provisinal targets during the Third Plan period would be 75,000 tons per annum and 125,000 tons per annum during the Fourth Plan period. Indications are that the capacity of the Indian Aluminum Plant at Hirakud will be doubled and two new units, one of 10,000 tons and the other of 20,000 tons are likely to be established at Mettur and in Koyna Project areas respectively, during the the Third Plan.

For the production of aluminium, electrical energy is considered as a raw material in as much as it consumes 22 kWh per kg. of metal produced. A smelter of 10,000 tons capacity would require power to the extent of 25,000 kW.

Fertilizers

In India where 82% of the population is sustained by agriculture, soil fertilisers occupy an important position. The First Plan envisaged the expansion of capacity for nitrogeneous fertilisers in terms of ammonium sulphate from 78,670 tons in 1950/51 to 489,000 tons in 1955/56 and a production of 46,304 tons to 450,000 tons. During the First Plan substantial quantities of nitrogeneous fertlisers were also imported and the total consumption of ammonium sulphate increased from 275,000 tons in 1950 to 610,000 tons in 1955/56. Based on the agricultural targets of production of be achieved, through the increased use of manure & fertilizers and the anticipated rise in the acreage under irrigation, the targets for the Second Plan are 382,000 tons in terms of fixed nitrogen. The increased demand will be met by expansion of Sindri Fertilizer Factory from 70,000 tons to 117,000 tons in tems of fixed nitrogen and the setting up of new fertilizer projects as under:

Plant Location	*Annual Capacity fixed nitrogen ('000 tons)*
Nangal	70
Rourkela	80
Bhilai Durgapur	7.2
Neyveli	70

The fertilizer plant at Nangal will manufacture Ammonium Nitrate by the electrolytic process and the project will require 160,000 kW of power which will be supplied by the Bhakra-Nangal Project. The likely annual targets for the Third & Fourth Plan periods have been estimated at 880,000 and 1200,000 tons in terms of fixed nitrogen respectively.

Railway Track Electrification

Railway traffic in India has increased enormously since the Second World War. The total tonnage handled by the Indian Government Railways has increased from 108 million tons in 1951/52 to 129 million tons in 1955/56 and is expected to reach 162 million tons by the end of Second Plan period. The transport of coal for consumption in locomotives engages so much of rolling stock that at times of emergency other essential movements have to be cut down. Furthermore, the use of high grade coal in steam locomotives constitutes an uneconomical method of its utilisation. With a view therefore to conserve the country's limited resources of high grade coal which is required essentially for metallurgical purposes and also to promote efficiency of operation and developing additional capacity of tracks economically, it has been decided by the Railway Board to electrify some of the tracks during the Second Plan period. According to the latest decisions in is proposed to take up track electricification of 2,317 km. during the Second Plan, giving priority to those sections which are considered necessary for dealing with the heavy traffic arising from the establishment of steel mills. No final decision regarding track electrification during the Third and Fourth Plan periods has been taken so far but further sections totalling 3,350 km. are stated to be under consideration for being taken up during next two Plan periods.

Water Supply & Drainage

A great deal of existing as well as future power demand for this category is entirely dependent upon the financial competence of the local administrations to pay for this amenity. But one thing is obvious that with the rise in the standards of living and increase in the per capita income, such essential amenities as better drainage and supply of filtered water will have to be introduced in semi-urban and rural areas also.

Irrigation

The power requirement is dependent on the number of waterings required for each type of crop, the area of land to be irrigated and the nature of the soil. It has been estimated that out of 332 million gross hectares available in the country 189 million hectares is cultivable area, but the area irrigated with assured supply of water was only 21 million hectares at the beginning of the First Plan. During the First Plan about 4.25 million hectares were to be added from major and minor irrigation projects. It is proposed to bring under irrigation an additional area of 8.5 million hectares during the Second plan period, raising the total irrigated area to about 21% of cultivable area.

Power Demand versus Power Availability

As indicated in the foregoing table the total demand in India from utilities and non-utilities if the power requirements were to be met adequately and without restriction, is estimated at 4.62, 8.19 and 11.80 million kW at the end of Second, Third and Fourth Plan periods. The provisional targets of installed generating capacity are 6.9, 11.5 and 22.0 million kW for the corresponding periods.

The results of the preliminary load survey indicate that if the sanctioned programme of industrial development for achieving the targets of production set for for the Second Plan were to progress unhampered, the overall target of installed generating capacity of 6.9 million kW for the same period would have, after allowing for the necessary standby plant capacity, just about met the overall estimated demand of 4.62 million kW. But this does not mean that shortage of power would not be felt by individual States. Considering the fact that surplus in a few power systems may not be transferable for want of or inadequacy of capacity of transmission lines, the load survey indicates that areas like D. V. C., West Bengal, Andhra Pradesh and even Madras would be confronted with such a situation. In fact the latest indications are that due to foreign exchange difficulties which the country is presently facing, the commissioning of some of the power projects may be delayed by about a year or so. The total generating capacity now estimated to materialise by the end of the current Plan would be of the order of 6.01 million kW. However, it is felt that the demand may also not materialise fully according to expectations, as it is understood that for want foreign exchange, licenses for the import of plant and equipment have not been granted to some industrial units that had been originally permitted to be set up under the Industrial Development Act of 1956.

The demand of power by the end of Third Plan period, as estimated, is of the order of 8.19 million kW on the assumption that the industrial development does not get restricted due to shortage of financial resources or delays in the availability of power. The tentative target of 11.5 million kW for the installed generating capacity by the end of this period may however just suffice considering the improvement that is likely to come about in the Plant Demand Factor with the development of grid systems.

During the Fourth Plan the demand has been assessed to increase to 11.8 million kW only which appears rather a conservative estimation. A more realistic picture would emerge when somewhat definite indications regarding the planned programme for developments in the various fields for this plan period become available.

Comparison of per capita Consumption of Electric Energy

The annual per capita consumption of electric energy for the country which stood at 14.0 kWh in 1950/51 rose to 25 kWh at the end of First Plan and is estimated to rise to about 50, 84, and 115 kWh by the end of Second, Third and Fourth Plan periods respectively. This is represented graphically in Plate No. 1. Plate No. 2 depicts the per capita consumption for other countries as compared to India for the year 1953.

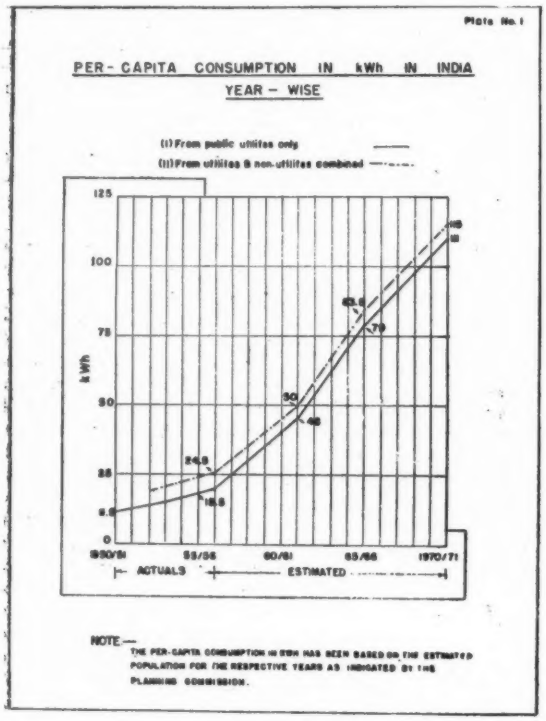


Plate 1.

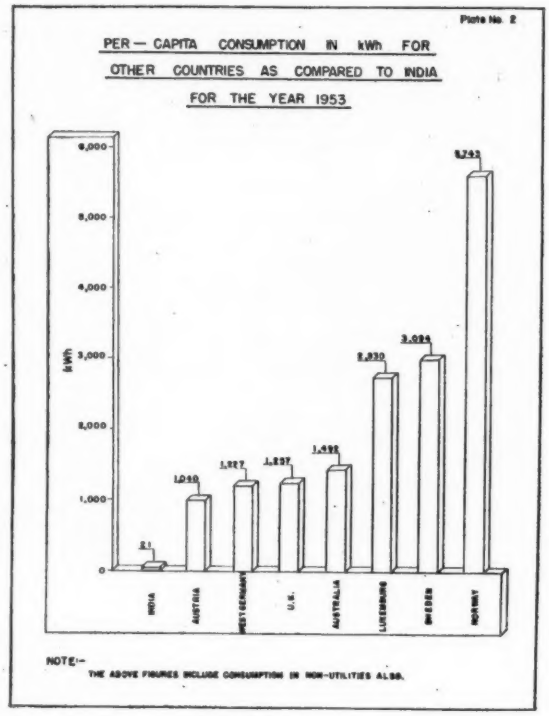


Plate 2.

Continued from page 27]

Power Requirements of India during the Second, Third and Fourth Plan Periods

The hydro resources of the country as assessed at present from the available survey topo sheets, are estimated at over 40 million kW. This represents the potential for the sites which are capable of being developed economically on the basis of present day costs. More detailed investigations are likely to reveal additional sites, thus increasing the available hydro electric potential of the country considerably. Apart from this, on the borders of our country, particularly in the Himalayas and on the Brahmputra river, very large hydro-electric resources exist. With the tenchnical developments in the high tension transmission systems, it may not be uneconomical to tap these resources for the mutual benefit of border countries and India. The present known hydro-electric potential is, more or less adequate to meet the load demands in all the States except West Bengal, Bihar, Madras and Bombay up to 1986. In the case of West Bengal and Bihar, even though the number of hydro-electric sites that are available for exploitation are limited, the coal resources of the areas are very large. In particular, the extent of availability of poor quality coal which is not useful for any purpose other than power generation is understood to be very large. Further, with the establishment of large sized, washeries for securing the required quantity of coking coal for steel plants, huge quantities of middlings will be available which could be beneficially utilized for generation of power. In the case of Madras and Bombay, the hydro resources get exhausted earlier than other states, The availability of lignite in Madras and low grade coal in Andhra provide additional sources of thermal power generation and the neighbouring States of Kerala and Mysore which have some surplus hydro resources can meet the power demands of the southern region as a whole. Similarly hydro resources of the States of the Madhya Pradesh and Mysore also serve as an extra source of power supply to Bombay. In order to exploit the power potential of the country as a whole in the most economical manner, the proper approach would be to establish inter-connected regional grids so that the non-availability of resources in one state does not handicap the power development of the whole region

Requirement and Resources for Power Generation India

By A. LAHIRI and A. GHOSAL
Director and Scientific Officer
Central Fuel Research Institute

PART I: ASSESSMENT

Beginning from the 19th century, and particularly in the 20th., the standard of living of people in any country has been practically synonymous with consumption of commercial energy. Man, by himself without the aid of external energy, can do little more than keeping himself alive. It has been estimated, for example, on the basis of average output of work against average intake of calories that the total man-power of India could be equated to approximately 10 million tons of coal per annum. In other words, a dozen or so of Bokaro thermal power stations could possibly do as much work, or produce as much goods as the entire man-power of India, assuming that it was possible for a robot to guide production. However, this great man-power can become a very effective source of production, if adequate horse power was placed at the disposal of each worker.

The average per capita income of a country, therefore, appears to be closely related to the energy consumption, since productivity is largely dependant on the number of horse power available per worker in any country. A significant part of commercial energy is also for domestic comfort contributing to a higher standard of living. It is, therefore, not surprising that the demand for energy is rising steadily in most countries of the world and the rise is fairly steep for the so-called undeveloped or underdeveloped countries, which are being transformed from an agrarian economy to industrial urban type through intensive and planed industrialisation.

Power as a Criterion for National Prosperity

Although the interconnection between energy consumption and economic indices follow a fairly complicated pattern and it is difficult to forecast one from the other mathematically, nevertheless, there is a broad correlation between total energy consumption and total national income industrial and, agricultural production.

Fig. 1 shows relation between per capita income and total energy consumption of several countries. It will be seen that India is practically at the bottom of the rung. This figure also illustrates the lee-way that has to be made up.

The rate of increase in population (approximately 1.2 per cent per annum) makes it imperative that social, technical and industrial development must be progressively accelerated if India has to increase the standard of living of her people even to a modest degree compared to the developed countries of the West or even that of Japan.

The per capita food intake, production of steel and transport facilities can be taken as fair indices of the standard of living of a country. It will be seen from Table I that there is a broad relationship between the per capita generation of electricity and that of the standard of living. This table merely illustrates a facet of the relationship prevailing between per capita national income and total energy consumption.

Table I

	India (1956-57)	*USA* (1954-56)	*UK* (1954-56)	*USSR* (1956)
1. Food intake/cap (k. cals/day)	1.700 (appxy.)	3000	3000	2500
2. Steel/cap. p. a. (tons)	0.0045	0.710	0.389	0227
3. Transport:				
(*a*) Net ton-km/cap. p.a.	164	4937	711	4854
(*b*) Pass. km/cap. p. a.	171	291	656	707
(*c*) Vehicles/1000 people	0.9	360	90	141
Electricity generation per capita p.a. kWh	30	3695	1573	1000

Table II illustrates the percentage contribution of electricity to the total energy consumption of some of the countries, and of India in particular.

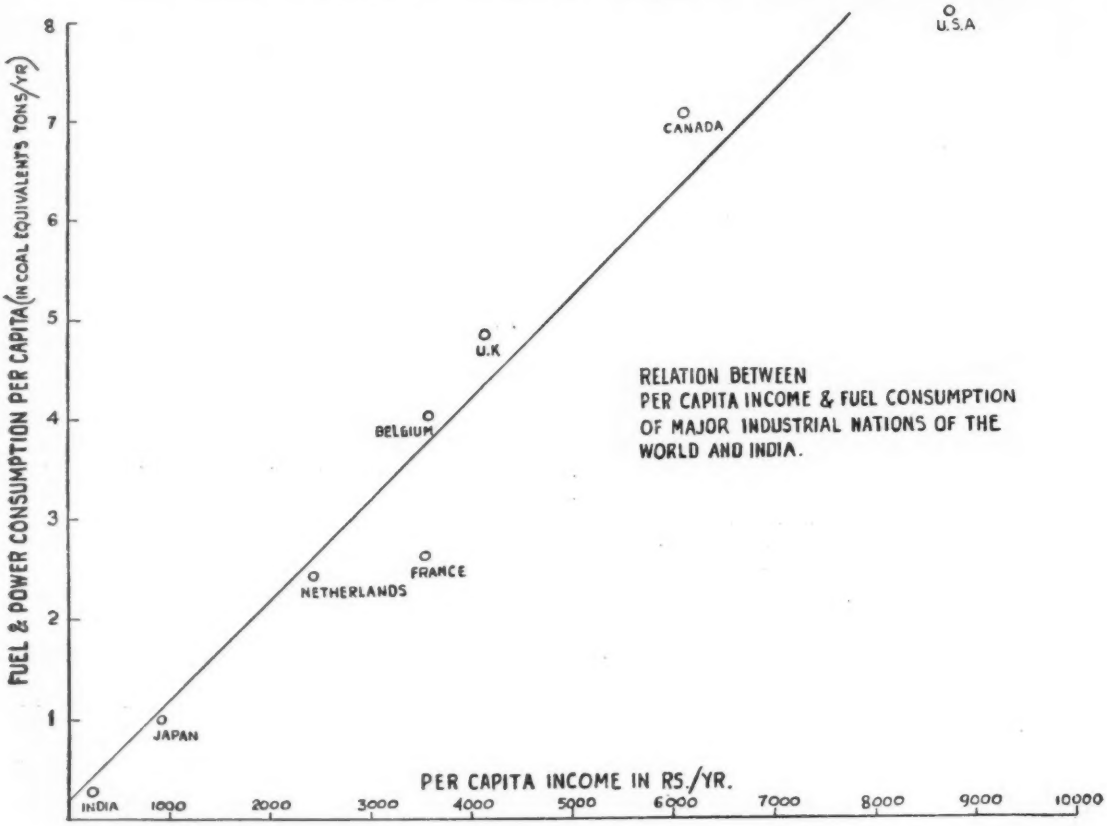


FIG.1

Table II

Contribution of Electricity Generation to Total Energy Consumption

	Total Energy consumed (m. t. coal equivalent)	*Total Electricity generated (m. t. coal equivalent)*	%
USA (1950)	1,487	192	13
USSR (1955)	487	68	14
OEEC (1954)	700	196	28
India (1954)	38*	6	16

Commercial energy
Assumption : 1000 kWh = 0.6 ton of coal.

Although the contribution of electricity to the total energy consumption varies from country to country depending on the resources of energy available in the country as well as the social and technological standards attained, the contribution of electricity to total industrial output and, therefore, to gross national production is a vital one and far outweighs its seemingly low percentage contribution to the gross energy intake. Fig. 2 illustrates diagramatically the per capita generation of electricity in 1956-57 of some of the industrialised countries and India.

It is evident that the horse power available per capita in India is extremely low.

It is, however, difficult to correlate the various indices of national prosperity with that of generation of power for a country like India, where the development is practically at the lowest level. Past statistics can help but little in forecasting the future trend. It will be seen from Fig. 3(*a*) and 3(*b*) that the trend of development of electricity for the USSR., which is practically the only country whose statistics are available for comparison in relation to the planned development, that the pattern of growth in the initial period, i.e. between 1928 and 1940 was quite diffierent from that in the later years, say, between 1950 and '55.

Whereas in the 1928-40 period the generation of electricity had to be increased at a very rapid pace in order to achieve a moderate increase in national income and gross industrial production, the USSR of 1950-55 followed a different course where the index of power generation with 1950 as the base, more or less followed closely the increase in the index of national income. These two figures illustrate that there is a considerable lag between generation of power and increase in the rate of production in the initial periods

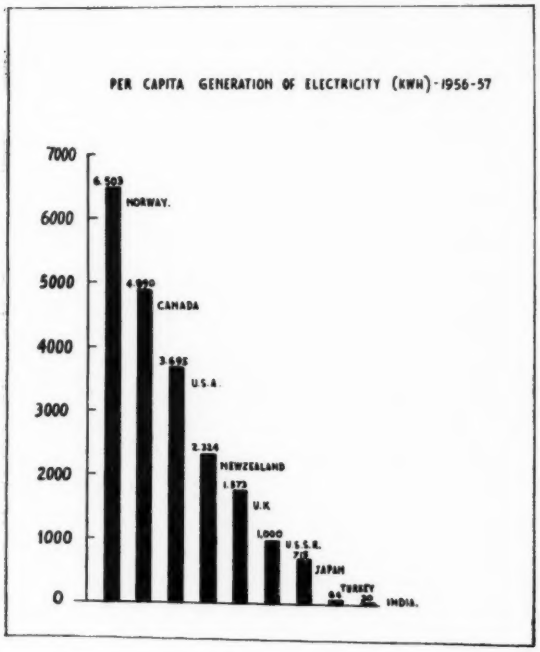


FIG. 2

of industrialisation. In other works, for rapid industrialisation of a country, power has to be put on the shelf, rather than load on the shelf. In India, so for, the trend has been first load on shelf rather than the other way about, although Fig. 3 (*c*) shows that even in India the rate of increase in production of electricity had to be well ahead of the rate of increase in national income and industrial production.

The production of electricity is a capital intensive industry. Further, in order to achieve the target for power production, resources also have to be developed in time, not only the raw materials required for generation of power, including availability of water, but also resources for manufacture of equipment such as steel, electrical goods, transmission facilities instruments, training of personnel, etc. It is, therefore, necessary to have a perspective of the trends in development of electricity for a foreseable period, say, for the next three Fiver-Year Plan periods, i.e. upto 1975-76.

It is interesting to recall in this connexion the slogan of Lenin that: "Electricity plus Soviets equals Communism". Lenin with his keen foresight predicted the need for placing the horse power in hand before the target of industrial production could be achieved. It is regrettable to note that in the planned development programme, so far, little attention has been paid towards establishing the 'means of production' for producing electricity based on indigenous resources. Although plans have been laid for production of steel, heavy machinery, mining equipment, chemical industry, etc., practically little or no thought apparently has been given to the question of production of 'means of production' of electricity in India. The approximate capital investment per kW of installed capacity is of the order of Rs. 1,000/- at present, of which foreign exchange constitutes more than 70-80 per cent.

The purpose of presenting this paper is first to make an assessment of the requirements of electricity in future in relation to the total energy requirement and to discuss the availability of resources for achieving the targets, as well as to take into account for planning some broad technological features which form the prerequisite for achieving the targets in relation to national resources.

There is urgent need for increasing the efficiency of power generation as well as that of availability of the installed kW in order that the resources required for energy consumption be minimised to the limit. The average efficiency of generation of electricity in India in recent years has been of the order of 17-18 per cent compared to 27-28 per cent of BEA and 30-32 per cent of the USA. It has been stated that the total increase in production of power in the United Kingdom in the past ten years or so, has been achieved without a corresponding increase in the consumption of coal for generation of power, and the saving is assessed at approximately 17 million tons of coal. The requirement of coal per mWh electricity generated is 0.8 ton at present for India. In the assessment of requirement of our resources, we have presumed that with the obsolescence of the old plants and installation of new plants of higher efficiency, utilising powdered coal firing technique and higher load factor, by 1975 this ratio will be decreased to approximately 0.5 ton per mWh produced. This is an important assumption, but not unrealistic, in view of the developments in modern technology in combustion of coal, utilisation of high steam turbine pressures, lower requirement of power for generation of electricity, etc. Supercritical boilers have already been experimented upon for a number of years in the USSR with success, achieving steam pressures of the order of 4800 lb per sq. inch and 1200°F temperature. Powdered coal firing in cyclone furnaces with slag tapping has resulted in combustion efficiencies of the order of 92 per cent and above, and it is claimed that in the United States, efficiency in the generation of power in large thermal power stations has reached the level of 40 per cent compared to 30-32 per cent maximum achieved in India so far. In the USSR., single turbines producing upto 600 MW are under installation and generation of electricity in units of 300 MW turbines are now quite common. A similar trend is noticeable in India and generation capacities have increased progressively upto 75 MW per unit and plans are now in hand for single units of 125 MW capacity to be installed even in the Second Plan Period.

The efficiency that may be achieved in the generation of electricity in future in India may somewhat offset the requirement of resources as assessed in this paper, but the trend and the order of the magnitude may not be very different from what is possible to assess even at this stage from statistical trends. There are, however, factors of national economics which may largely upset our calculations. A particular feature

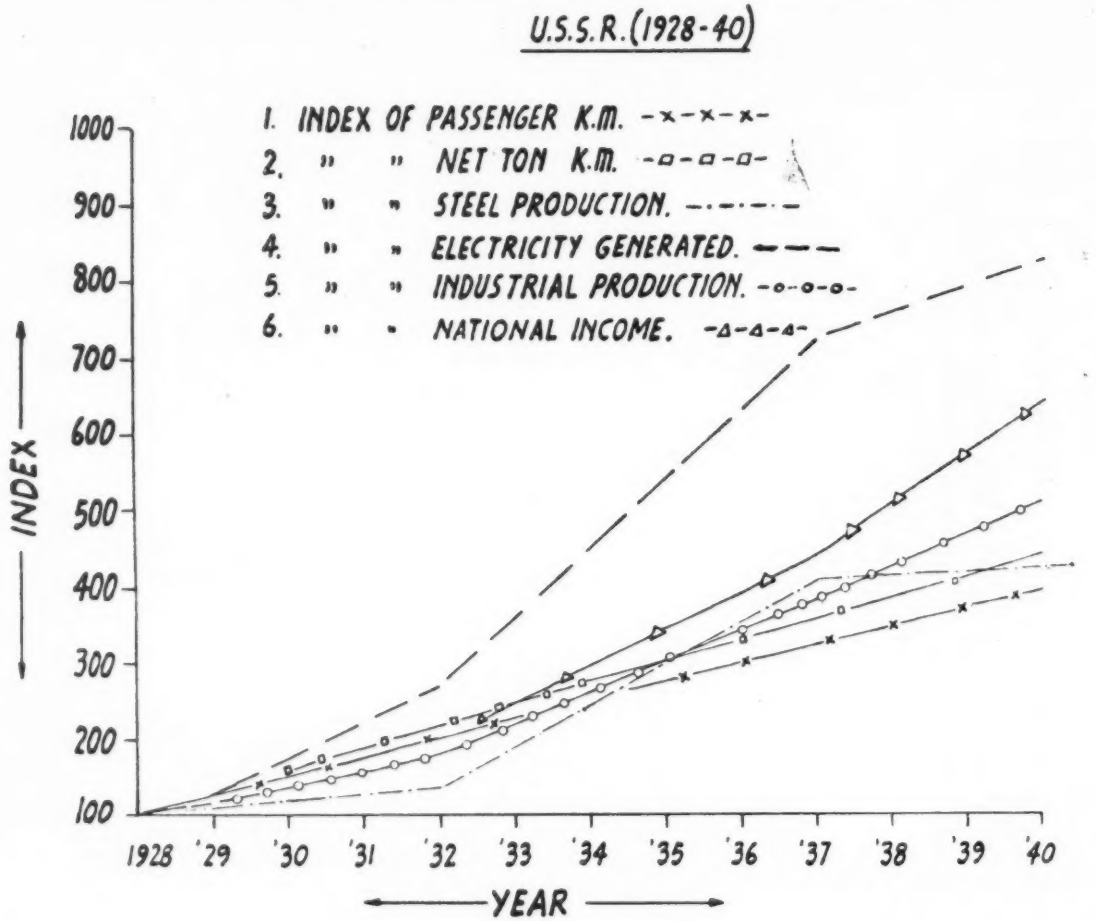


FIG. 3(*a*)

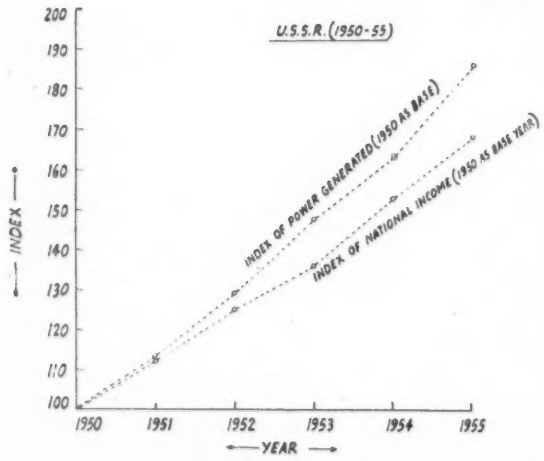


FIG. 3(*b*)

that has to be borne in mind in this connexion is that the consumption of energy of rural population will increase with increase in the standard of living.

Table III shows the percentage consumption of electricity in India in different sectors such as industiral domestic, etc., and that of several other countries.

Table III

Utilisation of Power by different Consumer Groups
(India compared with other countries)

Consumer group	*India* (1955)	*USSR* (1937)	*OEEC countries* (1954)	*USA* (1950)
Industry %	54.7	69.0	58.3	53.7**
Domestic, commercial, etc. %	17.1	13.7	26.7	32.1
Traction %	4.7	3.2	12.8	—
Irrigation and agriculture % *	6.3	0.9	—	—
Losses %	17.2	13.2	11.1	14.2
Total %	100.0	100.0	100.0	100.0
Total generated (10^9 kWh)	10.8	36.2	327.1	388.8

* includes 'water works'
** includes irrigation and traction.

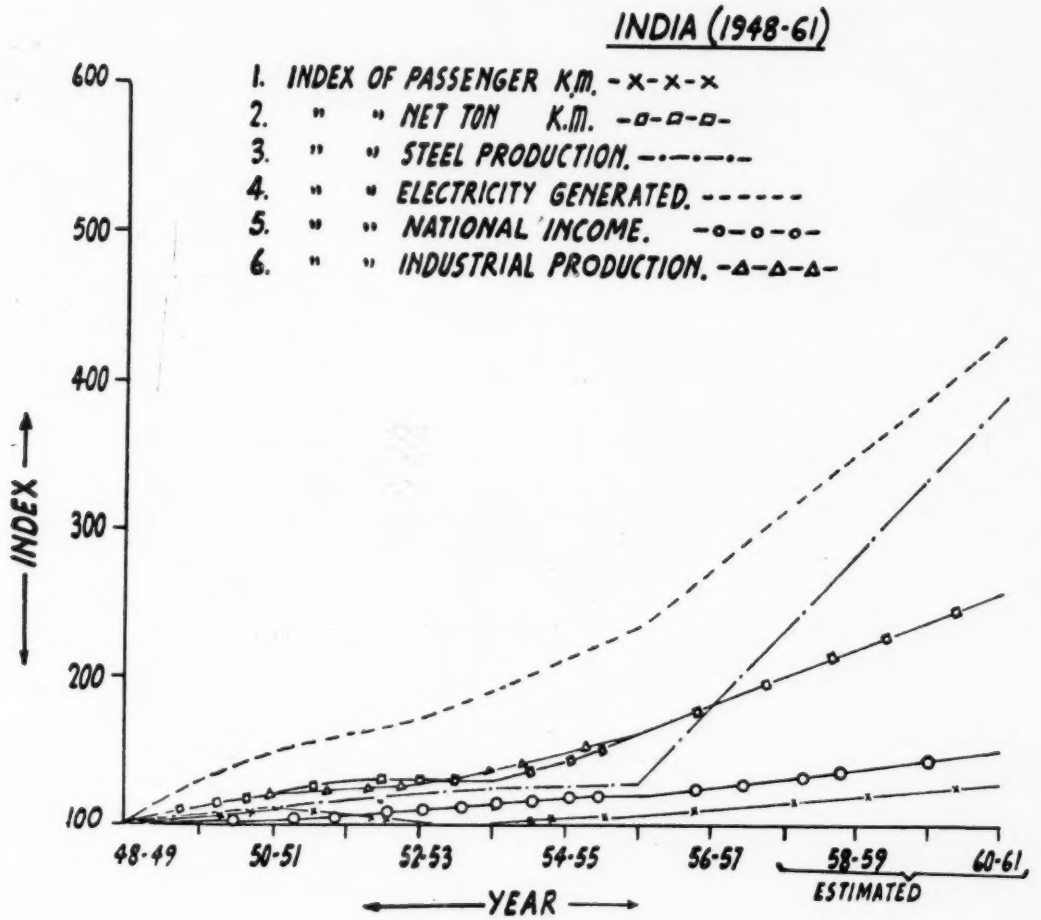


FIG. 3(c)

Table IV shows that the domestic share instead of increasing, is on the decline. On the other hand, there has been and will be an increase in per capita income of the country. As a result, the energy requirement for domestic and possibly agricultural purposes will veer round to petroleum fuels, particularly kerosene and middle distillates leading to a severe imbalance in production pattern of petroleum products.

Fig. 4 shows the assessment of requirements of middle distillates and Table V shows import of petroleum products in India for the last five years.

Table IV

Utilisation of Power by Different Consumer Groups in India

Sl. No.	*Consumer group*		1952	1953	1954	1955	1956
1.	Domestic	%	10.3	10.3	10.1	9.9	9.7
2.	Commercial	%	5.5	6.0	5.9	6.0	5.7
3.	Industry	%	52.4	54.0	54.2	54.7	55.1
4.	Traction	%	5.3	5.4	5.0	4.7	4.2
5.	Public Lighting	%	1.2	1.2	1.2	1.2	1.2
6.	Irrigation	%	3.5	3.2	3.1	3.0	3.3
7.	Water works	%	3.6	3.6	3.6	3.3	3.3
8.	Losses	%	18.2	16.3	16.9	17.2	17.5
	Total		100.0	100.0	100.0	100.0	100.0
	Total generated, excluding self-generating establishments, (in mill. kWh)		6120.3	6697.2	7521.8	8592.5	9662.1

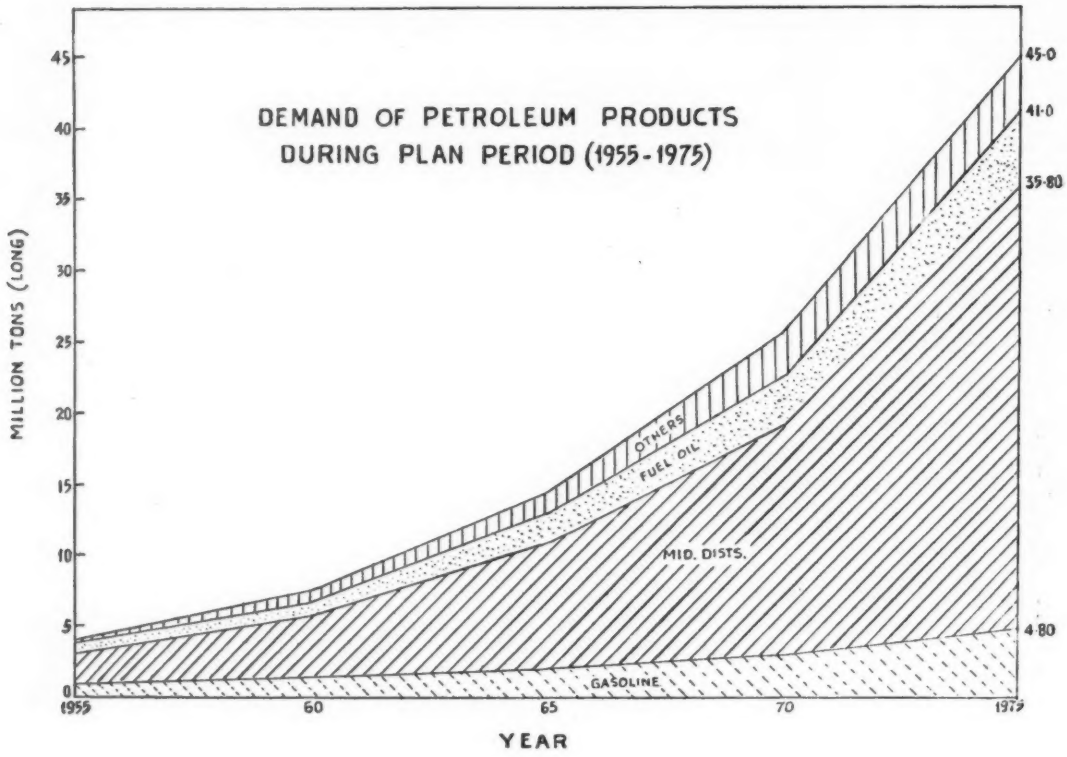


FIG. 4

Table V

Imports of Petroleum Products in India (Rs. crores)

Products	*Year*								
	1949	1950	1951	1952	1953	1954	1955	1956	1957
Motor spirit	16.33	17.87	24.37	25.18	30.90	24.87	9.08	5.00	6.31
Petroleum other than motor spirit	0.05	0.08	0.48	0.74	—	0.09	0.27	0.36	2.05
Kerosene	15.11	17.65	19.12	21.85	27.48	28.67	19.53	22.17	26.02
Diesel oil	6.84	6.86	9.01	9.45	10.92	12.94	5.39	11.73	27.10
Fuel oils	5.98	4.95	5.76	5.47	7.95	6.21	0.97	0.47	0.37
Batching oils	1.19	0.88	1.17	1.79	1.28	1.22	1.18	3.27	9.39
Mineral Turpentine	0.06	0.08	0.09	0.14	0.22	0.16	0.08	0.25	0.22
Others	1.13	0.70	1.07	1.12	1.29	1.35	11.52	24.38	34.47
	53.63	55.14	70.85	77.06	84.80	83.00	54.95	73.19	10.03

The assessment in Fig. 4 has been made on the assumption that the contribution of electricity to domestic sector will not be very different from what prevails at present or in the near future. Even at present, the demand of kerosine, which is largely consumed by the rural population, is of the order of 31 per cent of the total petroleum products consumed in the country and has been increasing steadily in the post-war years. The production of kerosine type of fuels, even if large discoveries of oil were made in India, in normal refining practice is such that it can never keep pace with the demand of such an order. In other words, there will be growing imbalance between the production pattern of petroleum fuels and the consumption pattern, leading to heavy imports of middle distillates of petroleum, kerosine in particular. Whether there should be deliberate attempt to avert such an adverse situation in economic and trade balances by following a policy of distribution of electricity to replacepetroleum fuels in domestic consumption is a matter for consideration at the highest levels, but it seems apparent that even on the basis of social justice, the availability of power for domestic consumption would steadily increase.

At present only 4 per cent cof the population enjoys electricity in their homes. Our consumption p. c. of power for domestic purposes among those enjoying electricity, is of the order of 90 kWh/year, and may

increase to a modest target of about 500 kWh/year by 1975-76 with a trebling in national income. Even if 20 per cent of the population were to consume electricity, the domestic sector alone will require 50 billion kWh of power. If this amenity could be extended to 40 per cent of our people by 1975,-76 then the domestic requirement alone will account for a 100 billion kWh. The per capita consumption of electricity for domestic purposes in the United States was of the order of 2000 kWh/year in 1950. It is likely to increase to about 5000 kWh/year by 1975-76, where 95 per cent of the population enjoyed electricity in 1950 and where 100 per cent of the people will have power for domestic use by 1960-61.

A compromise, therefore, has to be struck in any assessment between what is utopian and what is desirable on the one hand, and between what is desirable and practicable on the other. In our calculations, therefore, we have often given two limits of assessment ranging between the practicable and the desirable.

Assessment of Future Requirement of Power

The assessment of future requirement for India has been calculated on three different bases, viz.,

Basis (*i*) Relation between total real national income and total generation of power ;

Basis (*ii*) Presumption that the development of power in India will roughly follow world pattern for industrialised countries, viz., doubling in the generation capacity of power over every five years, and

Basis (*iii*) Relation between index of generation of electricity and index of production.

Assessment according to Basis (i)

Table VI gives the total national income and power development in India between 1950 and '60-63.

Table VI

National Income & Power Generation in India

Year (*t*)	*National Income* 1948-49 *prices* (1000 *crores Rs.*) (X_t)	*Electricity generated* (*Billion kWh*) (Y_t)
1950	8.9	6.58
1951	9.1	7.51
1952	9.5	8.00
1953	10.0	8.68
1954	10.3	9.58
1955	10.4	10.78
1956	10.8	11.96
1957	11.3	—
1958	11.8	—
1959	12.3	—
1960	12.9	22.00
1963	15.0	—

It is evident that the relationship between total national income and total generation of power is intrinsic and, therefore, the approximate requirement of power can be calculated from the planned increase in total national income as outlined by the Planning Commission. In the table it has been assumed that the targets for second Plan will be achieved and the national income for each financial year has been adjusted to the 1948-49 prices, and the generation of electricity has been taken as the actual for each calendar year.

In Fig. 3(*a*) and 3(*b*), was have already shown that there is a considerable time lag between increase in availability of powr and increase in national income. On an average, for India in its present status of development, we have allowed a time lag of approximately 3 years. On the basis of Table VI and these assumptions, the following regression equation can be derived:

$$\log_{10} Y_t = -.155 + .1002 X_{t+3} \quad \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where, X_{t+3} = National income (thousand crores Rs.) at 1948-49 prices in the year t + 3.

Y_t = Total power generated (billion kWh) in the year t.

The validity of this relationship is confirmed by the fact that the correlation coefficient (r) is as high as + 0.99. On the basis of equation (l) and on the assumption that the national income to be achieved in 1970-71 as planned by the Planning Commission will be achieved, the requirement of power can be calculated and these calculations are given in Table VII.

Table VII

Year (*t*)	*Estimated National income-'48-49 prices* (X_{t+3})	*Power requirement-(Billion kWh)-from equation* (*I*) (Y_t)
1960-61	15.0	22.3
1965-66	19.3	60.1
1970-71	22.0	112.0

It has been assumed that the energy relationship may hold upto 1970-71 in view of the 1928-40 relationship in the USSR. The calculations have not been projected beyond 1970-71, when a substantial increase in industrial production will be achieved, in view of the changing 1950-55 relationship shown for the USSR. Therefore, projection of equation (l) to beyond 1970, i.e. beyond he fourth Five-Year Plan on the basis of norms for the period 1960-70 may not be applicable to India of post-1970.

On the basis of these calculations, the requirement of electricity will be of the order of 60 billion kWh in 1965-66 and 112 billion kWh by 1970-71.

(*ii*) Assessment according to Basis (ii)

It has already been stated that the world average for industrialised countries indicate a doubling of power consumption every five years, i.e. about 15 per cent increase per annum. The USSR of pre-war period (during its first phase of planned development between 1928 and '38) showed a trebling in production and consumption of power. In Table VIII estimates are presented: (*a*) on the basis of a smooth doubling in

every five years, and (*b*) on the basis of trebling of power requirement in the third Five-Year Plan, followed by doubling in subsequent Plan periods.

Table VIII

Power Requirement for India

(Billion kWh)

Year	*Basis 2(a)*	*Basis 2(b)*
1960-61	22	22
1965-66	44	66
1970-71	88	132
1975-76	176	264

Whereas the assessment according to the Basis 2(*a*) is considerably lower that that of Basis (1), Basis 2(*b*) is considerably higher for the 4th and 5th Five-Year Plan periods than that arrived at according to Basis (1). It is likely that the country may follow an intermediate course.

Assessment according to Basis (iii)

In this case, an attempt has been made to develop the structural relationship between index of power generation and that of production of industrial goods. This basis is more reasonable for assessment of requirement of power in view of the very high contribution of consumption of power in the industrial sector to the power consumption pattern in the country. Table IV shows that nearly 60 per cent of the power consumption in the country is for industrial production and a parallelism has also been sought between the relative indices in post-war India as well as the USSR between 1928 and '55. The equations for both the countries are almost indentical so that a common equation can be used for estimation purposes. Table IX shows the relative indices for India and the USSR and the regression equations for the two countries are given below:

Table IX

India			U. S. S. R.		
Year	*Index of production (1951=100)*	*Index of Electricity (generation. (1951=100)*	*Year*	*Index of production (1928=100)*	*Index of electricity generation (1928=100)*
1948	78.0	62.6	1928	100	100
1949	82.0	67.1	1932	213	270
1950	87.8	87.5	1937	446	724
1951	100.0	100.0	1940	646	966
1952	103.6	106.5	1945	593	866
1953	105.6	115.5	1950	1119	1824
1954	112.9	127.5	1955	2065	3402
1955	122.1	143.4			
1956	132.6	159.2			

Let x=Index of production; y=Index of electricity generation. The regression equations for India and the USSR are as follows :

India: $y = -75.6 + 1.78 \times$ (corr. coeff. $= +0.99$) . . (2a)

USSR: $y = -84.3 + 1.69 \times$ (corr. coeff. $= +0.99$) . . (2b)

The high correlation coefficient for both the equations suggests that the degree of precision in estimating index of power generation in terms of index of production is high. Since the coefficient in equations (2*a*) and (2*b*) are very close, for the purposes of estimation, equation (3) can be taken on the basis of average of the two equations.

$$y = -80 + 1.73\,x \qquad (3)$$

Regarding the rate of increase in industrial production, the following two alternative assumptions have been made:

(*a*) that the index of production of 250 at the end of the Second Five-Year Plan will increase at the rate of 10 per cent compound in every subsequent year;

(*b*) that the index of production of 250 at the end of Second Five-Year Plan will increase at the rate of 15 per cent compound in every subsequent year.

The power requirement calculated for assumptions (*a*) and (*b*) are given in Table X.

Table X

Power Requirement for India (Basis 3)

Year	*Index of production (1951=100)*	*Index of electricity generation ('51=100) from eqn. (3)*	*Power requirement Billions kWh (1951 generation=7.5B kWh).*
		Hypothesis (a)	
1960-61	250	353	26
1965-66	442	685	51
1970-71	782	1353	101
1975-76	1386	2318	174
		Hypothesis (b)	
1960-61	250	353	26
1965-66	500	785	59
1970-71	1000	1650	124
1975-76	2000	3380	254

The requirements as obtained on Basis III (*a*) show good agreement with those obtained from Bases 1 and 2. Basis 3(b) gives higher estimates than those obtained from Bases 1 and 2.

It will be seen that the assessment on the Basis of 3 (*a*) is close to Basis (1) and the assessment of Basis 3 (*b*) is close to that of 2 (*b*). Again, it can be hypothised that the country will follow an intermediate course.

In Table XI, the above Bases of assumptions are tabulated and the averages have been calculated for Bases 1,2 (*a*) and (3) and 2 (*b*) and 3(*b*) separately. It is possible that the first is an underestimate and the second is an overestimate. The average of these two final estimates is given below:

Table XI

Power Requirement (Billion kWh) on different Bases

Year	*Basis 1*	*Basis 2(a)*	*Basis 3(a)*	*Average*	*Maximum Requirement*		
	(1)	2(a)	3(a)	*of Basis* (1,2a & 3a)	*Basis* (2b)	*Basis*(3b)	*Agerage Basis* (2b & 3b).
1960-61	22	22	26	23	22	24	23
1965-66	60	44	51	52	66	56	61
1970-71	112	88	101	100	132	112	122
1975-76	—	176	174	175	264	214	239

Table XII

Power Requirement (Billion kWh)

Year	*Estimate* (1)	*Estimate* (2)	*Average*
1960-61	23	23	23
1965-66	52	61	57
1970-71	100	122	111
1975-76	175	239	207

It has already been stated that the requirement of power will depend largely on the social and economic structure in the future. The assessments tacitly assumed a smooth rate of industrialisation without any revolutionary break-through either in the industrial or in the social spheres. As stated earlier, these assessments can be or are even likely to be severely upset by economic structure of the country in future in relation to the energy demand for its vast population and with a steady increase in the standard of living. Increase in consumption in the domestic sector alone can severely upset the assessments made above, but again, we have to assume and strike a compromise between what is utopian and what is desirable on the one hand, and what is desirable and practicable on the other.

There are, however, special factors which have to be borne in mind in relation to generation of power in India, apart from the requirement of domestic sector. Paucity of availability of high quality coal for traction, which in most countries consume nearly 20-30 per cent of the total energy consumption and paucity of petroleum fuels and adverse balance in foreign exchange situation may force the country to large scale electrification of traction. Indeed, the recent Experts Committee on Consumption of Coal by Railways of the Ministry of Railways has assumed that at least 25 per cent of the traction requirements of the Railways by 1975 will have to be borne by electric traction.

The Committee on Utilisation and Assessment of Requirement of Coal in its report assessed that even 50 per cent of the Railway load may have to be carried by electricity by 1975-76. The justification of such assessments, widely varying though they are, will be evident from the fact that for the increased load on the Railways by 1975-76, (if the Railways were to be solely dependant on steam traction) 100 million tons of coal will be required for traction alone, for which it will be necessary to produce at least 300 million tons of coal and process it in beneficiation plants to meet the quality required. Even the assumption of 25 per cent of railway load to be borne by petroleum fuels will mean a consumption of diesel oil of the order of 4 million to 5 million tons per annum i.e. equivalent to the present total consumption of combustible petroleum products, for Railways alone. Already 826 miles route of Railway electric traction has been planned (including areas of rail traction in coal-bearing areas) during the second Five-Year Plan. Utilisation efficiency of energy alone calls for such a change. The efficiency of a steam locomotive is of the order of 5 per cent and that of electric traction is of the order of 13 to 14 per cent. The investment in the generation of power for electric traction will make corresponding savings in investment for mining and processing of coal and its transport.

Even in the industrial field, it is likely that many industries in India will be power intensive. Next to iron, India's richest resources in metals are aluminium and manganese both of which are power intensive in their production. Since almost every country requires about 8-10 per cent of alloy steel of its total steel production and consumption, the production of alloy steel will also call for large demand of power. The same is true for certain sectors of heavy chemicals such as caustic soda, fertilizers, carbide, etc. In addition, there is an urgent need for increase in food production in the country, and the most vital factor for production of food, apart from supply of fertilizers, is irrigation. Power irrigation which is at present nominal may have to be stepped up considerably in future in order to provide food for the increasing millions and to avert a national disaster which will follow dependance on import for the country's food supply.

Thus, the final assessment given in Table XII (Estimate 2) may not be an overestimate.

In Tables 13 (*a*, 13 (*b*) and 13 (*c*) are presented the final assessments for the power requirement of India in billions of kWh installed capacity required, estimated population and per capita generation of electricity. Fig. 5 shows the estimates of electricity generation and installed capacity on the basis of Table 13 (*a*). It will still be seen that the per capita generation of electricity in India will be less than half that of present-day Japan.

Table XIII (a)

Power Requirement for India (Minimum) Es. (1), Table XII.

Year	*Electricity generation required (Billion kWh)*	*Installed capacity required (Million kWh)*	*Estimated Population (Millions)*	*Per capita generation of electricity*
1	2	3	4	5
1960-61	22	6.9	408	54
1965-66	52	15	434	120
1970-71	100	25	465	215
1975-76	175	44	500	350

Table XIII (b)

Power Requirement for India (Estimate 2, Table XII)

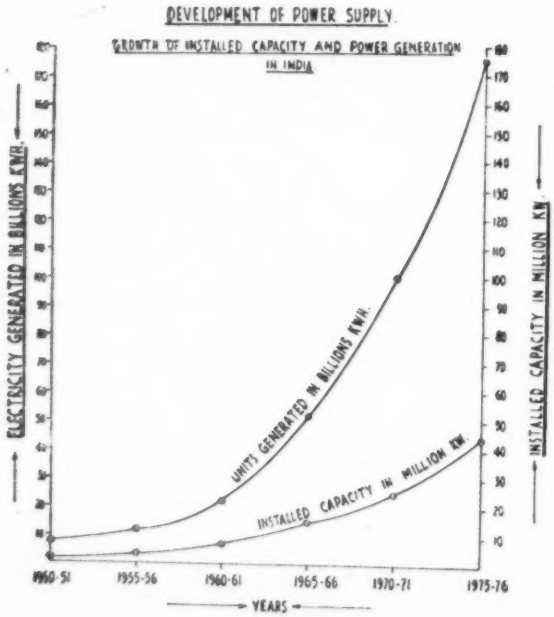
1	2	3	4	5
1960-61	23	7	408	56
1965-66	61	17	434	141
1970-71	122	31	465	362
1975-76	239	60	500	478

Table XIII (c)

Power Requirement for Iudia (Average of Estimates 1 & 2, Table XII)

1	2	3	4	5
1960-61	23	7	408	56
1965-66	57	16	434	131
1970-71	111	28	465	239
1975-76	207	52	500	414

FIG. 5



Resources of Power

Assuming our assessment to be valid for the total requirement of power, we have now to assess the contribution of the various resources towards the total requirement.

The hydro-electric potential of India has not yet been fully explored, but as far as the economically exploitable potential is concerned, it is estimated to be around 40 million kW installed capacity. Out of this, only about 1 million kW has been installed so far and about 2.5 million kW is proposed to be installed by the close of the 3rd Plan. Even if the entire potential is exploited, which is well beyond the realm of feasibility, it will provide only an equivalent of 0.16 ton of coal per capita, whereas by 1976, the per capita electricity consumption will be equivalent to about 0.2 ton of coal. Actually, based on the findings of the U. N. Study Group, the per capita coal equivalent of the hydro-potential economically exploitable in this country will be a mere 0.03 ton as against the planned 0.2 ton.

Besides, there are some obvious disadvantages of hydel pojects. The output of power is seasonal, the flow of most of the Indian rivers being seasonal. This would necessitate either construction of huge reservoirs, which is certainly very expensive and raises the cost of kWh generated or integrating it with thermal power stations of suitable capacity in order to even out the seasonal fluctuations and to derive the maximum benefit out of the project. Another disadvantage is the long time required for the completion of hydro-electric projects due to which its power output cannot be obtained for a phased programme of industrial development. Owing to these and various other reasons, hydro-electric resources of the country cannot be depended upon solely for large-scale power development.

Nuclear energy has already started making inroads into the power pattern of some Western countries, particularly the U. K. India has substantial resources of uranium and thorium oxide, fissile fuels required for nuclear power stations. But, the technological know-how in the field of nuclear engineering is yet too inadequate to lead one to envisage its large-scale replacement of conventional fuels for electricity generation for a few decades to come.

In their report on 'Energy Requirements of Europe', the team of OEEC Experts have cautioned against the possible undue enthusiasm over nuclear energy and have predicted that for many years to come coal must remain the mainstay of the Western European energy economy. It need hardly be emphasised this is more or less true for India also, where there is already an abundance of cheap thermal power resources. An assessment has it that the contribution of atomic energy to the total commercial energy in India by 1975 would be about 2 per cent. Even for Western Europe it is only about 8 per cent after making a beginning in 1965.

This leads to the conclusion that atomic power can

contribute only a small proportion of the total power needs of India for some years to come.

We have, thus, to fall back largely on our fossil fuel resources for development of power. The fossil fuels include coal (and lignite), petroleum and natural gas.

Despite new discoveries which have been made recently, or being made presently, of oil reserves near Naharkatiya in Assam and oil and gas in the Cambay region of Saurashtra and other areas of Western India, the part these fuels may play in the overall power pattern is negligible.

However, assuming contribution of hydro power and other sources at the maximum possible level, Table 14 (*a*) and 14 (*b*) give the percentage contribution from different sources towards total generation of power. It will be seen that progressively the contribution from coal is likely to increase and that, by 1965-66, the contribution from coal is likely to be between 46 and 54, by 1970-71, between 56 and 64.

Table XIV (a)

Distribution of Power Sources in Future (Billion kWh)
(on the assumption of minimum requirement)

Year	*Thermal (coal)*	*Hydro*	*Others (Diesel, nuclear sources, etc.)*	*Total*	*% of (2) to(5)*
1	2	3	4	5	6
1960-61	9	13	1	23	39
1965-66	24	26	2	52	46
1970-71	56	38	6	100	56
1975-76	115	50	10	175	66

Table XIV (b)

Distribution of Power Sources in Future (Billion kWh)
(on the assumption of desirable requirement)
Estimate 2, Table XII

1	2	3	4	5	6
1960-61	9	13	1	23	39
1965-66	33	26	2	61	54
1970-71	78	38	6	122	64
1975-76	179	50	10	239	75

On the basis of these two estimates of the breakup of the resources of power generation and on the basis of assumption that the efficiency in the generation of power from coal will increase from 0.8 ton per mWh to 0.5 ton per mWh by 1975-76, the requirement of coal for generation of power for India in the subsequent Plan periods is likely to be as follows:

Table XV (a)

Reqairement of Coal for Power Generation
(On the assumption of minimum estimates, Col, 2, Tab. XIV (a).

Year	*Thermal Electricity generated (Billion kWh)*	*Coal required for produing 1000 kWh*	*Coal requirement (Million tons per annum).*
1	2	3	4
1960-61	9	0.8	7
1965-66	24	0.7	17
1970-71	56	0.6	33
1975-76	115	0.5	57

Table XV (b)

Requirement of Coal for Power Generation
(On the assumption of estimates given in Col. 2, Table XIV-(*b*)

1	2	3	4
1960-61	9	0.8	7
1965-66	33	0.7	23
1970-71	78	0.6	46
1975-76	179	0.5	90

The consumption of coal for generation of power in the United States, in spite of a sizeable contribution from oil and natural gas and hydro, is at present of the order of 160 million to 170 million tons per year and it is assessed that even wih the contribution from atomic energy, the contribution from coal by 1985 it likely to be of the order of 400 million tons per year. Although India is not likely to achieve this standard possibly during the present century, the assessment of requirement of coal as outlined above, does not appear to be unreasonable, though the magnitude is high compared to the present level. In the following section, the availability of resources of coal and the technoloical requirements will be considered, which have to be followed, if India is to obtain her supplies of fossil fuels for her energy requirements, particularly for generation of power.

PART II

RESERVES OF COAL

It may be stated at the outset that even the known reserves of coal in India are more than sufficient to meet the energy requirements of the country for many years to come. It has to be emphasised, however, that coal industry is rather inflexible and that increase in production cannot be obtained by merely opening the tap and that it requires heavy investment at least 8-10 years in advance to obtain the projected output from a mine. It is, therefore, important that fuels so produced be utilised efficiently and in a scientific

manner, so that we can obtain energy at the lowest possible 'real' cost. It took the nature about 200 million years to store in the ground these stockpiles of 'fossil fuels', which civilization is now consuming in a flash of geological time.

The known reserves of coal in India are at least 120,000 million tons. During the past few years of intensive exploration in localised areas in Raniganj, Jharia, Bokaro, North Karanpura, South Karanpura, M. P. and Godavari coalfields have shown great reserves of coal which had not been known before. Similarly, large reserves of lignite have been discovered in Madras, and are reported to have been discovered in other areas. It is almost true to say that with every borehole we sink, new reserves of coal are being unearthed. There are vast tracts in M. P., Orissa and Bihar, which are yet unexplored, and it is possible that large reserves of coal underlie the vast areas of Deccan trap in Peninsular India.

However, although the total reserves of coal may be large, our present knowledge shows that the reserves are fairly localised in Bengal, Bihar, M. P. and Andhra areas, and much of our reserves are of inferior quality. The inferior quality and restriction in geographical occurrence imply that if we are to make the best use of our natural resources, we have to think and plan both in terms of space and technology.

The first and foremost is to have accurate data on quality of the resources. These are being gathered by the Regional Coal Survey Organisations of the Central Fuel Research Institute. Six such Stations at Jharia, Raniganj, Ranchi, Bilaspur, Hyderabad and Jorhat (Assam) are now functioning. The surveys, so far, show that the sources of coking coal are located only in West Bengal and Bihar areas, but non-coking coals of low grades and low ranks occur abundantly in other areas, which with suitable plant design can be most profitably utilised for generation of power. The quality of coals occurring in most of the areas outside Bengal, and except the coking coals of Bihar, are largely of inferior variety high in ash and in most parts, high in moisture and of non-coking quality. Even in Bengal and Bihar, which contribute at present 80 per cent of the total production of coal in India, the resources of good quality—both coking and non-coking—are limited and are not likely to last for many years at the rate of increased consumption envisaged.

Utilisation of Inferior Coal

The task of research and technology, therefore, is chiefly to devise ways and means to utilise the inferior varieties of fuels—coking, non-coking as well as lignitic—in order to produce energy, gas and chemicals at the lowest possible cost. It is, thus, inevitable that emphasis should be on technological research and economical and spatial integration of coal-based industries, and of processing of coal in particular. Each method of treatment produces a number of by-products the maximum utilisation of which alone can bring down the real cost of products. For example, in mechancial cleaning of coal, large quantities of high ash fuels (known as middlings and rejects) will be produced. Even the rejects in many instances, contain 50 per cent or more of carbon and can be utilised for combustion or gasification in suitably designed plants. In fact, the inability to utilise these residual fuels will render coal preparation in India uneconomic or result in prohibitive costs for cleaned fuels.

Cleaning of coal and mechanised mining will lead to reduction in size of coals and, therefore, utilisation must aim at direct use of such high ash fine coal.

Combustion of high ash coals produces large quantities of ash which constitute a serious handicap and loss both in the form of heat carried away with it and in subsequent disposal. Utilisation of ash in a suitable manner such as after slagging for building material and road construction, as mixture in cement, in preparation of insulation material, etc., may lead to substantial economies in production of power.

The combustion of high ash fuels automatically implies that units for utilisation must be of the central type and of large capacities in order that specialised equipment can be used for obtaining high efficiency. Logically, therefore, a pattern of thermal power generation has to be evolved to suit the distribution and quality of our coal resources, through establishment of central thermal power stations of large capacities interconnected by high voltage transmission grids for distribution of power over wide areas.

Price of Coal

In a paper on Equalisation of Price of Coal, the question of price of coal has been discussed on the basis of its useful and delivered heat value as a measure to reduce bulk transport of coal over large distances, and thus to free the limited supplies of railway stock for more essential and more profitable pay-loads. A distribution policy has been suggested which, coupled with equalisation of price of the chief industrial raw materials, such as iron and steel and cement, will go a long way in providing opportunities for industrialisation over a large part of India, by providing energy and raw materials for industry on an equitable basis. It will also enable utilisation of the resources in the most economical manner by preparing the mined coal and separating it into different qualities for supply for different purposes and for the distance ranges. The following table shows broadly the distances over which different qualities of fuels for combustion and steam-raising may be supplied. In view of the recent and impending changes in price ofe oal, the figures may require further review:

Zonal Distribution Scheme for Coal

Above 35% ash	at pithead or washery
Upto 35% ash & moisture.	up to 75 miles
Upto 30% ash & moisture.	75 to 200 miles.
Upto 25% ash & moisture.	200 to 400 miles.
Selected Grades 20% ash & moisture Domestic coke.	above 400 miles equalised price for 150 and 250 zonal price basis.

The cost of fuel to the Indian industries is yet very

low (3% of total value of production), due chiefly to the low pithead price. The bulk of the cost is due to transport and, therefore, a national policy for distribution of coal on the lines as suggested above has to be evolved in order that efficient utilisation and long term planning can at all be possible.

It is, therefore, suggested that the Government consider a rational price structure of coal on the principle that inferior coals shall be cheaper—and considerably cheaper—than quality coals, whose proice in India is probably a fifth of that in other countries.

A steep price difference between qualities will provide the rationale for improvement in quality and at the same time encourage utilisation of lower quality fuels and foster fuel economy in those industries which need the better quality coals. An increase in price of coal, without a change in the comparative price structure of the qualities is against national interest, as this will merely lead to a general price increase without any concurrent national gain.

Utilising Inferior Coal for Power Generation

For combustion and utilisation of inferior varieties of fuel containing 30 per cent or more ash, it willl be necessary to adopt powdered coal firing in dry or wet bottom boilers. For ash content exceeding 35 per cent, wet bottom boilers are more suitable and where ash fusion characteristics permit, the cyclone type of boilers with slagging of ash is the latest modern development in boiler design and economy.

In view of the fact that inferior grade and high moisture coals are also fairly difficult to grind, the adoption of cyclone type of boilers where fusibility characteristics of ash permits its application (or where it can be modified by doping) should be widely adopted.

Technological considerations further imply that such power stations should be of large capacities not less than 30,000 kW per unit and preferably 50,000 to 100,000 kW units.

The slagging of ash in wet bottom boilers will eliminate the problem of fly ash and grit emission (which offend Public Health Laws) and at the same time, enable production of a controlled quality of slag for further utilisation for manufacture of puzzolana, blending with Portland cement, making of road metal, manufacture of mineral wool for insulation purposes, etc.

Thus, as far as possible and as far as load demand and distribution characteristics permit, such large thermal power stations with pulverised fuel firing should be coal-based.

The fact that in pulverised fuel firing, ash penalty ratio is nearer unity, enables utilisation of inferior coals over wider ranges of distances, than has been indicated in the table above. The minimum penalty for increment in ash in the above table has been taken at 1.2 for the higher grades and approximately 1.5 to 2 for the lower grade coals for assessing the useful delivered heat value of coals. In the case of pulverised fuel firing (dry or wet bottom), and particularly if utilisation of ash can be achieved, the ash penalty is more nearly of 1:1 ratio, although cost of equipment is more. In the case of pulverised fuel firing for large central power stations, therefore, the ranges for distribution and corresponding quality can possibly be shifted by one group, i.e. whereas coals of Grade III or so may be supplied to normal steam and power generation plants upto a distance of 75 miles, in the case of large central thermal power stations, the distance may be increased, say, upto 150 miles and corresponding shift can be made for the other ash and distance ranges. With rationalisation of coal production from the outlying coalfields outside Bengal and Bihar, this will enable generation of power at comparative costs even with low grade fuels.

The question of transport of such coal for power generation by hydraulic transmission (as is being done at least in one case in the U. S. A.) should also be explored to relieve rail transport. The fact that short distance freight charges are high, lends special significance to pipeline distribution of coal in large quantities over short distances.

Wherever possible in generation of steam for processing, back pressure turbine should be used for generation of power as byproduct, and in straight generation of steam, pressure over 1200 p. s. i. (and 900°F) should be used for securing further economy in power generation. The average efficiency of power generation in India is only of the order of 17% as against 27% for the British Electricity Authority.

In view of the inevitable production of large quantities of slack coal in coal preparation plants, as well as due to increased mining of coal by mechanical means, it is necessary to restrict the supply and demand of lump coal particularly of better qualities to the maximum possible extent, and if possible, to restrict its use chiefly to Railway locomotives. A matter of interest is that the slack coal is generally not only more washable in character, but the natural slack is generally lower in ash. Thus, wherever slack coal can be utilished, whether for combustion or for process requirement, such as in brick making, cement manufacture, etc., its use should be encouraged and supplier of lump fuels for such uses should be restricted.

A large quantity of coal—approximately 5 million to 6 million tons—is consumed in small power stations or in vertical or Lancashire shell type boilers. These and other steam and power generation equipment generally fall into three categories according to their age and efficiency. Those established before 1930 are extremely inefficient, apart from being designed for higher quality fuels, which were then available. These should be progressively replaced by power from grid as indeed has been the recent trend. Where fuel situation necessitates, they should be replaced by more modern slack burning equipment.

Those established between 1930 and 1945 are more efficient and designed for slightly lower grade of fuels and with certain alterations and controls in utilisation,

be converted (e. g. by installing stokers or by wetting of slack and by increasing fuel efficiency measures) to utilise inferior varieties of coal, as well as slack coal.

The steam and power stations established since 1945 are generally of larger capacity and are designed to burn more inferior fuels.

Recent directives from the Planning Commission, the Coal Controller and the Central Water & Power Commission have done much to encourage construction of efficient thermal power plants based on low grade fuel. The Central Fuel Research Institute and its Coal Survey Stations have given much help to prospective power generation authorities, by indicating sources of coal, their quality and specifications for equipment.

It is, however essential that a more closely co-ordinated policy should be followed and it is suggested that a Standing Steam Power Station Licensing Committee should be formed.

The sizing of coal is often more important than the quality for many combustion appliances. The requirements of many types of stokers are specific in size-consist and in most cases constitute a serious disadvantage in so far as they cannot tolerate fines above or below a certain quantity. Much of these disadvantages can be obviated by controlled wetting of the coal and by adoption of spreader type of stokers in larger units and by installation of Oldbury type of stokers in small shell type of boilers.

In respect to smaller peak-load power stations of small or medium capacity, it may be of interest to investigate the possibilities of utilising fuel oil (which will be produced in large surplus quantities from the refineries) or by pulverized fuel firing in closed cycle in stationary gas turbines. This type of combustion appliance may be of particular interest in areas where water is scarce or of such quality that it requires expensive treatment, e.g. in Rajasthan.

Whereas the above recommendations regarding pulverized fuel firing are chiefly restricted to capacities above 10,000 kW, it is recommended that plants with installed capacity between 5,000 and 10,000 kW should be designed for utilising slack coal containing at least 30 per cent below $\frac{1}{8}$" size coal with suitable provision for intimately wetting the coal before combustion.

Such power stations or boilers situated with in 200 miles from source of coal should be designed for utilising coal with 20 to 22 per cent ash and 6 to 8 per cent moisture (at 60% RH at 40°C), those situated within 200 and 400 miles from source of coal should be designed for utilising coal with 16 to 18 per cent as with 6-8 per cent moisture (at 60% and 40°C) and beyond this range, selected grade coals should be supplied. (This will rarely be necessary in future, as with increased production from the outlying coalfields, most of the consumers will be within a distance of 400 miles from source of supply). If however, due to shortage of supplies any of these plants are to be supplied with coal from a source beyond their immediate neighbourhood, then the supplies should follow the quality and range distribution as given in table earlier.

Regarding coal for power stations below 5,000 kW also, the same rules can be applied, but there may have to be inevitable relaxation to these rules in view of the inefficiency or inflexibility of the older plants. As far as possible, these plants should be replaced by stoker-firing equipment.

Thus, wherever possible, either in the existing boilers or after modifications, every attempt should be made to use slack coal, the quality of which should be governed by the location of the consumer in relation to the source of supply.

Directives should also be given to convert smaller units to stoker-firing progressively, so that they can fit into this scheme of distribution. For any steam generation units to be erected in future, the above rules should be strictly adhered to. As a measure of detriment for use of lump coal, a stiffer price differential, which will automatically lead to avoidance of use of lump coal where it can be avoided, and will, at the same time, encourage conversion of existing equipment to slack firing should be adopted.

One of the major factors in achieving efficiency in power generation is the consistency in supply of coal both in regard to its quality and size. Whether the plants are designed for high or low grade coals, efficiency in operation can only be maintained if the supply is consistent. The general policy in distribution of coal for thermal power stations should be to locate a particular source for a particular consumer and not to change the source without adequate notice. Where larger power stations are concerned, the output of whole collieries may be allotted to a particular consumer or group of consumers. A boiler designed for slagging of ash cannot easily take a coal having refractory ash and vice-versa.

Indian coals are notoriously inconsistent even in the same seam, and before alllotting the outputs of major producers to major sources of consumption, the full survey details of the physical and chemical quality of coals should be taken into consideration. Thus, very close co-operation between the State Electricity Boards, the Central Water & Power Commission, the Coal Controller and the Central Fuel Reserach Institute is called for.

In order to supply consistent quality of coal not only for the general consumer, but also for the Railways, it may be worthwhile to consider preparation of coal even if by simple blending into two or three marketable grades at the major baseloading stations. The blending stations may or may not be equipped with washing facilities depending on the quality of coal produced, the nature of consumers to be served and the distances to which the coal may have to be transported.

Integration

As far as possible, the large central thermal power stations should be integrated with the planning

of washeries for coking or for non-coking coals. Such integration has already been achieved at Bokaro and will be achieved at Durgapur and at Dugda. It is also worthwhile to consider the location of cement manufacturing plants alongside some of the larger power stations, particularly those to be designed to produce slag ash. The opportunity of utilising the slag ash from the thermal power stations may often be nullified due to transportation costs either of the slag or of the cement clinker.

Washing of Coal and Utilisation of By-productct fuels

The cleaning of Indian coals in general is not a simple deshaling process, where only two products, viz., cleans and rejects are produced. Owing to the comparatively difficult washing characteristics of the Indian coals, three or more products are invariably produced and their economic cleaning cannot be often achieved in a single unit or plant. Due also to the varying outputs of coal even from the same coalfield and in view of the small production from individual seams and mines, the problem of cleaning of Indian coals is rather different than in U. K. or in the U. S. A. For the cleaning of Indian coals, in many cases, double or treble washing in different types of plants may be necessary. Investigations carried out at the C. F. R. I. have established beyond doubt the following characteristics about washing of coals from Jharia, Bokaro, Raniganj and M. P. coalfields.

(*a*) Better quality coals generally give better yields of clean coal;

(*b*) The cleaning characteristics of coal are progressively more difficult with requirement of lower ash in the cleaned product;

(*c*) The coals below 1″ in size generally have better cleaning characteristics than coals above this size;

(*d*) The percentage of ash in the middlings and rejects lies between 30 and 50 per cent, and thus, even the rejects are not actually refuse, as they often contain 50 per cent carbon;

(*e*) In majority of the cases, even one per cent reduction in ash in the raw coal by cleaning, on an average, produces 5 per cent in middlings and rejects and with more difficult types of coal (such as from the lower seams of Jharia and Bokaro fields), the percentage yield of middlings and rejects is often 10 per cent for every one per cent of ash reduction. This is also true when lower ash (say below 17 or 18 per cent ash in the cleans) is demanded, even for the medium quality coking coals.. Thus, production of 30 to 40 per cent of middlings and rejects is unavoidable in washing these types of coal.

These matters have been thoroughly investigated by a Committee appointed by the Coal Board and the findings have been published in the Report of the Coal Washeries Committee.

The production of middlings during the third Five-Year Plan alone will be of the order of 6.5 million tons per annum, capable of generation of 1600 mW of power.

While the immediate need is for upgrading by mechanical cleaning of coals of coking quality for iron and steel production, it may also become inevitable to clean and prepare fuels of noncoking quality for specific purposes such as long distance requirements and for the Railways.

Installation of a number of washeries have been proposed to upgrade non-coking coals for railway supplies. These will also produce large quantities of middlings and rejects, as will be evident from table no. XVI.

Table XVI

Summry of Estimated Products (Qualtative & Quantitative) obtainable from Central Washeries—Yields are expressed in mill. tons per year.

Central washeries	*Coalfields*	*Capacity in tons/hour (rated).*	*Clean coal*			*Raw slack-1″-0 produced after crushing plus 4″ and scd. at 1″*		*Middlings*		*Rejects*		*Sinks (Middlings) and (Rejects).*	
			Size	*Yield %*	*Ash %*	*Yield %*	*Ash %*	*Yield %*	*Ash %*	*Yield %*	*Ash %*	*Yield %*	*Ash %*
Central washeries for steel plants excluding those in private sector	Kargali	E. Bokaro	500	3″-0	1.63	15.8	—	—	0.39	28.5	.20	48.0	0.59	35.1
	Durgapur	Raniganj	400?	,,	1.01	16.6	—	—	0.08?	33.3	0.11?	48.4	0.19?	42.0
	Bhojudih	Jharia	250	,,	0.96	14.9	—	—	—	—	0.14	42.9	0.14	42.9
	Pathardih	Jharia	360?	,,	1.19	15.6	—	—	0.31?	32.5	0.12	55.2	0.43	38.8
	Dugda	Jharia	600	,,	1.74	15.1	—	—	0.53	34.8	0.12	57.2	0.65	38.9
Central washeries for Railays	Ondal	Raniganj	600	4″-1″	2.32	16.0	1.00	15.5	—	—	—	—	0.19	42.2
	Barkakana	Karanpura	500	,,	1.40	15.5	0.80	22.1	—	—	—	—	0.60	39.8
	Anuppur	C. India	400	,,	1.45	16.3	0.68	22.3	—	—	—	—	0.23	53.3
	Junnardeo	Pench and Kanhan Valley	300	,,	0.78	16.1	0.44	22.1	—	—	—	—	0.34	40.5
	Kothagudium	Singareni	400	,,	1.32	15.9	0.60	19.6	—	—	—	—	0.18	53.8

The requirement of coal on the basis of steam traction alone for the Railways may be of the order of 100 million tons by 1975, for which 300 million tons of coal will have to be raised and processed. In other words, if the Railways were to remain steam-based, then the entire requirement of coal for the country in 1975 will have to be processed for the Railways alone and that rest of the industries in India will have to be supplied with byproduct fuels obtained from processing of coal for the Railways. This position is on the face of it, absurd and, therefore, the Railways should plan their future development in such a manner that at least 50 per cent of their requirement will be met by electrification based on low grade fuels and/or hydro power obtained from National Electricity Grids and that 25 per cent of their requirements of future load be dieselised.

Size of Coal

Table No. XVII below shows the approximate requirements of coal in the Second Plan and subsequent

Thus, the fuels available in future for generation of power will not only be higher in ash content, particularly when these are derived as by product fuels from washeries, but also smaller in size. Increased adoption of pulverized fuel firing either of the wet or dry bottom types is the only solution towards this deterioration in quality.

Most of the stoker type of combustion appliances require graded coal and it will be increasingly difficult to supply coals of graded sizes and required quality power generation. It is, therefore necessary to envisage this future trend clearly and reorient the technique of power generation accordingly. For too many authorities still rely on advice of the manufacturers regarding the nature of equipment to be used without reference to the quality of fuels that may be available at present, or in not-too-distant-a-future.

Underground Gasification

There are also very large reserves of coal where

Table XVII

Statement showing coal requirements for major sectors: (Million tons coal equivalent)

Sl. No.	Sectors	Year 1955	1960	1965	1970	1975	
1.	Iron & Steel including coke for foundries, etc.	3.5	10.5	26	39.5	55	(washed and blended ?)
2.	Thermal	3.0	7.5	17	25.0	50	(including middlings. rejects and low grade coal)
3.	Domestic	2.5	5.0	20	50.0	70	(Sized non-Coking coal, sized middlings and briquetted fines)
4.	Railways	12.5	17.0	22	25.0	25	
5.	Brick & cement	4.0	8.5	12	15.0	19	
6.	Synthetic oil (F. T).	—	—	2	20.0	40	(mostly byproducts of washing and low grade coal)
7.	Miscellaneous	11.1	16.5	21	30.5	41	
	Total:—	36.6	65.0	120	205.0	300	

Plan periods as outlined by the Coal Council. It will evident that such large scale increase in outpur is only possible by adoption of intensive mechanisation in mining. At present, only a small part of the coal production is being obtained by mechanical cutting. It is well-known that mechanical mining seriously affects the quality of coal raisings due to intrusion of dirt bands, etc., which can be avoided in manual mining and also by reducing the size of coal and dirt pieces, which render handpicking impossible. Thus, increase in mechanisation of coal mines will contribute towards increase in ash contents of the raisings as well as deterioration in size of coal. At present, approximately 25-30 percent of coals produced are below 1" in size. With increase in adoption mechanical mining, it is not unlikely that 50 per cent of production will be below 1" in size in future. The sizing of coal will be further aggravated by crushing which is essential for upgrading of Indian coals in washeries. Fig. 6 shows the past trend in deterioration in quality of coal with increase in production and price of coal in India.

economic mining may not be feasible. The example of the U. S. S. R. in this respect is worth studying. Underground gasification of coal for production of lean gas suitable for generation of power either in conventional steam turbines, or in gas turbines is a matter which requires careful thought for future supply of resources of energy for generation of power.

Use of Carbonized 'char' for Power Generation

With the improved knowledge in the constitution and nature of coal and with the development in technology for processing of tar and other by-products, it is becoming evident that a time may soon come when burning of raw coal for generation of power will be considered an economic waste of a valuable raw material for chemical industries. A step towards this has already been taken in America, where 'Char' i.e. carbonised powdered fuel is being used for generation of power on a large scale in at least one plant and with the development of equipment for efficient burning of char, proposals are in hand for several more large scale installations of this type.

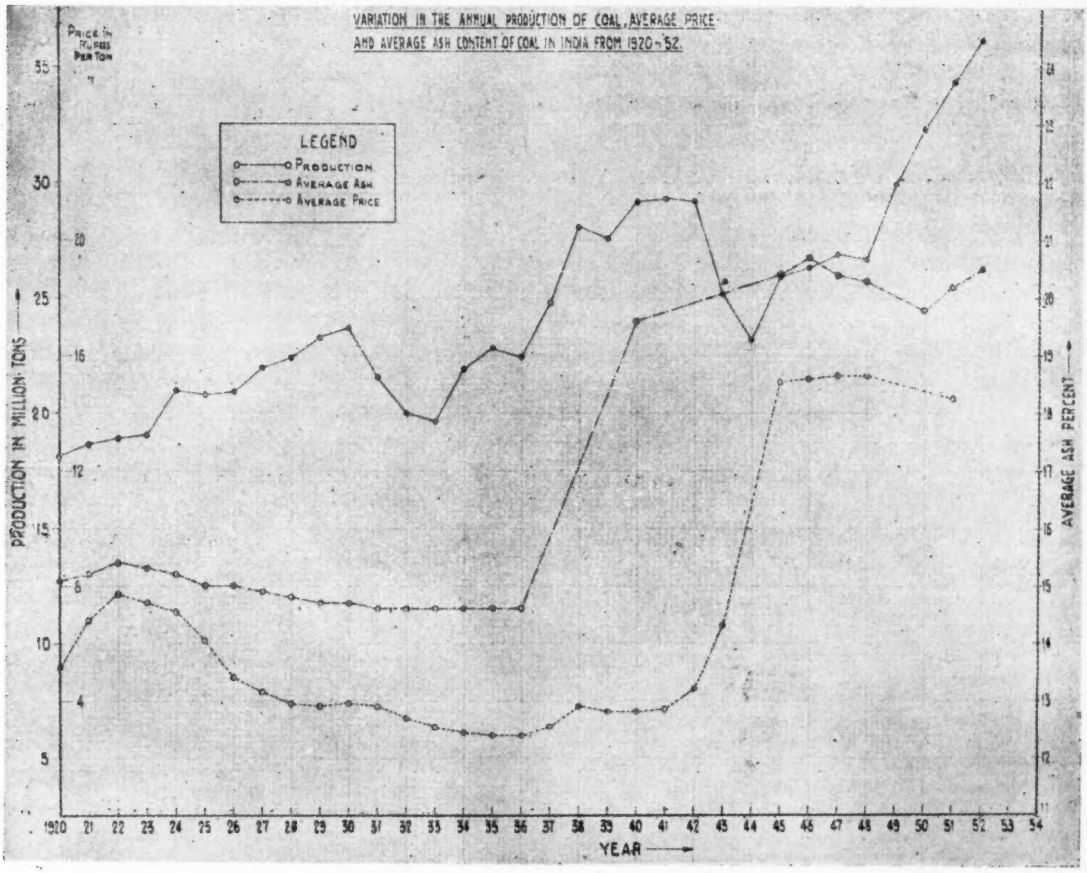

VARIATION IN THE ANNUAL PRODUCTION OF COAL, AVERAGE PRICE AND AVERAGE ASH CONTENT OF COAL IN INDIA FROM 1920-52.
LEGEND
PRODUCTION
AVERAGE ASH
AVERAGE PRICE
PRODUCTION IN MILLION TONS
AVERAGE ASH PERCENT
YEAR

Fig. 6. Variation in the annual production of coal, average price and average ash content in India from 1920-52

A technique developed during the past few years, known as 'Fluidised Carbonisation' enables powdered non-coking coal to be carbonised cheaply and at a very rapid rate which yields highly reactive powdered char and a very large quantity of primary tar (upto 10-12 per cent of coal carbonised) and gas. Whereas the char and the gas could be utilized for generation of power, the tar can be processed for production of diesel and/or motor and aviation fuels as well as chemicals. In the United States over 160 million tons of coal are being burnt for generation of power and it is expected that by 1980, about 400 million tons of coal will be required for generation of power alone. Even if the additional requirements only be met by carbonised char, nearly 20 million tons of low temperature tar will be available for production of liquid fuels and chemicals.

It should be realised that one ton of diesel oil is equivalent to about 10 tons of coal in a Railway locomotive. If, therefore, 100 tons of coal is carbonised it would yield 75-80 tons of char, 10 tons of tar and the rest as gases. If 10 tons of tar is converted to 8 tons of diesel oil, then by such a process, each ton of coal can give an effective value of twice its weight, if it were used in its raw form. Thus, of the requirement of 50-60 million tons of coal for generation of power, even if half is used in carbonised form, we may obtain 2-3 million tons of tar annually for production of diesel fuels and other chemicals. Such an integration is also being considered in the U. S. S. R., where a new technique known as the Sapoznikove process has been developed, for production of a highly reactive type of semi-coke suitable for generation of power, gasification or domestic use. Experts were of the opinion that during the course of the next few years, a hundred million tons of coal will be utilised in this manner in that country.

PLANNING FOR FUTURE

It will, therefore, be clear from the above that the authorities in charge of the planning of power generation should not think merely in terms of raw fuel and convenient plant and equimnent for immediate needs for power. It will be necessary to utilised more and more of:

(*i*) low grade and fine coal which can be cheaply mined by open-cut techniques from inferior quality thick seams ;

(*ii*) Utilisation of middlings and rejects containing higher ash (35-50 per cent) and high moisture which will be produced in large quantities from washeries being installed for preparation of coal for coking, as well as for other purposes such as for Railway supplies;

(*iii*) Utilisation of gas for generation of power from seams of coal which are economically unmineable; and

(*iv*) Integration of power generation with production of liquid fuels and chemicals by carbonisation of powdered coal of non-coking quality having high tar yields.

For achieving such integration, it will be necessary to locate the thermal power plants strategically so that minimum transport is involved in order to cheapen the fuel costs. *Such plants, therefore, will be more and more fuel-based rather than load-based.* It follows logically that load-based plants should only be considered when inescapable and for peak-load generation. It does not pay to transport coals of high ash and high moistture particularly in small sizes. It is even dangerous to do so with many fuels. Similary, if power generation be integrated with carbonisation plants producing tar, the plant should be designed in a manner that hot char can be used in order to achieve higher thermal efficiency.

Studies at the Central Fuel Research Institute have shown that non-coking coals of lower ranks, i.e. fuels which will be mostly available for generation of power, are also considerably harder to grind. In order to utilise our high ash fuels in the best possible manner and with the highest efficiency it is necessary to adopt powdered coal-firing for steam generation. For normal type of plants, coals have tobe ground to below 200 mesh in size. The consumption of power per ton of coal ground is of the order of 16-18 kW hr. With the harder coals which are mostly available, the cost of grinding will be still heavier. There are, however, techniques of combustion (such as the cyclone type of combustors referred to above) which can use coals upto ¼ in size and where the consumption of power for crushing is reduced to 4-5 kWh.

It has also been noted from studies carried out at the Central Fuel Research Institute that most of the coals in India have high melting points of ash, chiefly over 1400°C. For slagging type of boilers, which are the most suitable for high ash coals in general and for cyclone firing, the ash melting point should,however be 1350° C or below. The studies carried out at the Central Fuel Research Institute have shown that although many of our coals have high ash melting points, it is possible to reduce the melting point to a suitable range by doping with limestone and/or hematite. Researches have also shown that combination of limestone and hematite lowers the melting point faster with small rates of addition of the dope to the fuel. References can be made to the relevant publications of the Institute for details but it should be realised that for each fuel it is necessary to carry out actual experiments to ascertain the correct type and the amount of doping.

Design of thermal power stations, therefore, requires close collaboration with research organisations like the Central Fuel Research Institute and its Coal Survey Stations in order to ascertain and select the most suitable type of fuel and the correct design for efficient use.

Conclusion

The purpose of writing this section will be well rewarded if it can lead to a greater awarenses on the part of the authorities responsible for planning and generation of power the need for perspective in order that the fuels can be utilised most rationally and efficiently.

It may be concluded that even though the requirement of coal for generation of power for the subsequent plan periods will be high, the demand can be met—and economically—if a policy of integration and a scientific approach be followed as indicated above.

SPECIAL NUMBER ON

Indian Journal of Power and River Valley Development

on

Tungabhadra Project

To be published in March on the occasion of the Prime Minister's visit

Price : Rs. 7/50 nP.

Book your orders with :

The Manager at 6/2, Madan Street, Calcutta - 13

Power Development in India: Present position, Planning and Prospects

By J. L. D'SA
Chief Electrical Engineer
Government of Mysore

India largely being an agricultural country, the growth of electricity has been slow as compared with other countries. Until the Second World War, the supply exceeded the demand, even though such electric supply was mainly confined to a few urban areas of the country. With the impetus given to the industry by the war effort and later on by the industrialisation policy of the Government after the attainment of independence, the supply lagged far behind the demand. This situation was forecast several years ago by the industry but for some reason or another, power development commensurate with the country's needs has not yet materialised.

The problem of developing the power resources is, no doubt, an enormous one in a country of the size and population of India. Nevertheless, for nearly half a century, efforts have been made to develop power through hydro electric and thermal means and in this programme both the Government and private enterprise have participated. During the last decade, a determined drive has been made by the Government in the direction of electric power development and the establishment of the Central Waterways, Irrigation and Navigation Commission, now called the Central Water & Power Commission, is a recognition of the need for planned development of power.

Mysore can lay claim to the fact that it was the pioneer of all Hydro Electric Generating Stations in the East starting a Generating Plant at Sivasamudram with a capacity of 4400 kW in the year 1902. The capacity of this Station was gradually increased by stages to generate a total power of 45,000 kW. After further investigation another Power Station at Shimshapura was built, diverting the waters of Cauvery to generate power to an extent of 17,200 kW.

The demand for power by big industries like the Iron Works at Bhadravati, the Mysore Chemical and Fertilizers led to the establishment of a third Generating Station at Jog utilising the water of Sharavathi river, the power available from this project being 1,20,000 kW. The total installed capacity of the State was 1,79,200 kW and with the States Re-organisation, a small amount of power to the extent of about 8,000 kW. was added to Mysore by way of our share of power from the Tungabhadra Hydro Electric Project which became a joint venture of Mysore and Andhra.

During the first Year Plant he Mahatma Gandhi Hydro Electric Works which was already in service was expanded by adding four units of 18,000 kW each thereby adding a total installed capacity of 72,000 kW to the System.

The expansion of Mysore Iron and Steel Works at Bhadravati, the establishment of Central Government industries like the Hindustan Aircrafts Ltd, Bhrat Electronics (Private) Ltd., Hindustan Machine Tools (Private) Ltd., Indian Telephone Industries (Private) Ltd., absorbed all the additional power from the above hydel project leaving no margin for further expansion of industries in the State.

The State grew to nearly twice its original size as a consequence to States Reorganisation and the problem of power shortage has assumed a very serious position. With the exception of the Mahatma Gandhi Hydro Electric Works, no new power project was taken up during the first Five Year Plan.

The Second Five Year Plan

The projects included in the core of the Second Five Year Plan is (1) The Bhadra Hydro Electric Power Project and (2) The Tungabhadra Left Bank Power Project. These two projects which are under execution are expected for operation by 1960-61 the benefits being additional 25,000 kW firm power from Bhadra and 18,000 kW from Tungabhadra Project. The first stage of Sharavathi Valley Power Project consisting of two machines of 89.1 megawatts each, which is also under execution during the current Plan period is scheduled for service by 1961-62. This latter project is as yet not included in the core of the Plan.

While Mysore had a very early start in the field of hydel power generation, the State is at present faced with a serious power shortage. The additional firm power during the Second Plan will only be 43,000 kW and this will not be enough to meet the requirements of major industrial expansions like the Mysore Iron & Steel Works, Hindustan Aircrafts Ltd., Hindustan Machine Tools Ltd., and Bharat Electronics Private Ltd. There has been a large demand for power from the Small and Medium Scale Industries, which the State Electricity Board is unable to comply with. However, as a temporary measure to meet the normal increase in load like the domestic lighting and other essential requirements as well as the accelerated increase during the Plan all available spare capacity has been put into operation and in all the Generating Stations there is no stand-by unit at present. Several restrictions have been imposed on fresh power requirements while devices like staggering of working hours and of holidays are being adopted to meet the essential demands of the industry and agricultural power services. Such measures are resulting in serious loss in production restricting the economic development of the State reflecting also on the overal economy of the country. Several prospective industrialists have registered for power requirement and such industrial power requirements present the following brief picture.

Sl. No.	*Classification of Industry*	*Power requirement in kW.*
1.	Iron & Steel	50,000
2.	Electro-Chemical & Mining	222,000
3.	Paper Pulp, Rayon and Printing	35,850
4.	Food industries	1,310
5.	Textiles	5,445
6.	Research Laboratories and Industries	20,745
7.	Cement Plants	29,000
8.	Other Industries	5,525
	Total:	369,605

It may be briefly said that scope for utilisation of the anticipated power fromthe Projects is almost unlimited.

Prospects

In the past, the growth of industries detracted from the colonial nature of the economy was to a great extent responsible for the slow development of projects. As a first and very important step towards planned development of power the Central Water and Power Commission has undertaken a comprehensive load survey of the entire country. The Commission has done well in quickly assessing the power needs on a region-wise and country wide basis and their preliminary reports should be of considerabale value in formulating the schemes for the third Five Year Plan.

The developments in power generation today are proceeding on the basis, that steam, hydro and internal combustion prime movers have each their special scope under certain given conditions where the advantages of each form of prime mover have been correctly assessed and applied. Hydroelectric potential is for the most part located at sites far distant from industrial locations. The economic transmission of power is dependent on the magnitude of load transmitted. So it might prove better initially to provide thermal sources of powers at centres naturally suited for industrial development as a load-building device. Small nursery stations operating diesel oil with relatively cheap capital cost should be encouraged.

Speaking on the relative merits it is difficult to dogmatise on the economics of hydro and thermal stations. In a general way, the hydro power involves in greater capital including as it does the cost of one or more dams and other civil engineering features besides electical equipment. Hydro power plants usually have to be built to almost their full size *ab initio* and therefore there is often a long wait before the plant could be fully fully utilised and maximum return on capital outlay achieved. If a large artificial water storage is necessary for hydel generation and if the site is far removed from the prospective load centres, it may then be more economical to instal thermal plants, the determining factor in the latter case being the cost of fuel and its haulage. A combination of water and thermal plants would appear to be the most economic proposition especially where water supplies are seasonal or the cost of providing large dams to give an all year round flow is prohibitive. All relative factors have therefore to be carefully balanced in every individual case, the important factor being the cost of dams versus the availability, cost, haulage distance and reserves of thermal fuel. It should be remembered that the haulage factor has a direct burden on the national transport.

It may be said that the plan for power development should be a long range one i.e. visualising the trend of growth in the next 20 years should be taken as a basis. Further plans should be worked out to fit in the long range plan to achieve results in record time

Backed with experience and the results of the First and Second Five Year Plans, it should be possible to have a better framework for the Third Five Year Plan in the field of power developement and it is suggested that an effective contribution of both hydel and thermal power development in the Third Plan period may prove to be the best solution for a speedy development.

Power Development in India

By A. K. BHAUMIK
Chief Electrical Engineer and Electrical Adviser
Government of West Bengal

There is always a need to look back upon the 12 years period since independence and to assess what we have achieved during these eventful years keeping in view that other developed countries have reached a stage which India must avail of as early as possible to attain a moderate standard of living. This assessment may be done primarily under two contexts:

(1) Rate of progress—the conditions under which the nation started, and achievement made in the shape of 'gross national productivity'.

(2) In the context of world in general—progress achieved in India vis-a-vis countries with which a comparison could be made.

The above observations are all the more necessary in view of the fact that India being an underdeveloped country, her rate of progress must of necessity be faster than that in other 'developed' countries.

In recent years there has been a growing awareness of the relationship between per capita consumption of electricity and the standard of living enjoyed by the people of a country. Table I illustrates this relationship based on available statistics of a few countries and India.

Table I

Country	*Per Capita Consumption of Electricity*		*Increase In%*
	1948	1956	
India	11.5	20.70	80 %
O. E. E. C.	887 (1950 Figure)	1346	52 %
U. K.	880	1862	112 %
Germany	578	1612	180 %
France	614	1231	100 %
U. S. A.	2300	4095	78 %

In this article an attempt has been made to show the availability of energy resources and their utilisation made in India vis-a-vis a few other countries of the world. Endeavour has also been made in a very general way to show relationship of the production with utilisation of electric energy.

Growth of Generating Capacity in India

The capacity of the first generating plant installed in India was 130 kW (Hydro) by the Municipaliity of Darjeeling in 1897 i.e. 17 years after the Edison's invention of a generating plant for homestead lighting.

Table II illustrates the gradual development in respect of electricity supply industry in the country.

Scope of Comparison

The purpose of all comparison is to find out the degree of proximity of difference between comparable groups. Since the aim of India's successive 5 year plans is to stabilise the economy of the country at the level of developed countries it shall be in the fitness of things to confine our comparison to such countries as U. K., U. S. A., Germany, Canada, Sweden etc.

As it will be difficult to undertake detailed comparison between India and other developed countries individually within the short compass of this article, it is proposed to confine the study of comparsion between India and a group of countries which collectively approximates to Indian standard in respect of national income, productivity, area, population etc.

Table—II (a)

Growth of Installed Capacity in India

[Source : All India Statistics Books—CWPC]

Year/Period	*Installed Capacity*	*Type of Installation*	*Major additions during the period*	*Public or Private enterprise*
I. Early years				
1897	130 kW.	Hydro	Darjeeling Municipality	Local Government
1899	100 kW.	Steam	Calcutta Electric Supply	Private.
1902	4500 kW.	Hydro	The Mysore Darbar (meant for supplying Kolar Gold Fields).	Private.
1906	3000 kW.	Steam	Madras Electric Supply Corporation Ltd.	Private.
1906	2170 kW.	Steam	Cawnpore Electric Supply Co. Ltd.	Private
1909	4227 kW.	Hydro	Kashmir Govt. (Jhelum P.S. at Mahara).	Government.
1912	15000 kW.	Steam	Calcutta Electric Supply Corporation Ltd. (Cossipore P.S.)	Private.
1914	50000 kW.	Hydro	Tata Hydro Electric Power Co. (Khopoli P.S.)	Private.
1901-1920	6325 kW.	Diesel	In 25 towns including Ahmedabad, Allahabad Delhi & Karachi.	Mostly Private.
			(Aggregate of installed capacities of Steam, Hydro and and Diesel Plants in 1920—1,30,609 kW.)	

Table II (b)

Period	*Installed capacity as in 1947*	*Type of Installation*	*Major additions during the period*	*Public or Private enterprise*
II. Twenty-seven years between 1921 and 1947	757,457	Steam	Addition of 55 New Stations & extension to existing plants.	Mostly Private
	97,679	Diesel	Addition of about 360 New Towns & extension to existing plants.	Mostly Private.
	508,129	Hydro	Notable installation/addition Tatas (Bombay) 192000 kW. Sivasaundram .. 29250 kW Shimapura .. 19200 kW Pykara .. 18750 Ganga Canal (C.P.) .. 17400 Jogindarnagar .. 48000 Mettur .. 48000 Pallivasal .. 13500 Pykara extension .. 20000	Private. Mostly Govt.
Total ..	1363,265 (100%)		Steam installation .. 55.5% Diesel installation .. 7.2% Hydro installation .. 37.3%	

Table II(c)

INDIAN UNION

YEAR	INSTALLED CAPACITY							
	Steam		*Hydro*		*Oil.*			
	Installation (Kilowatts)	*Percentage of total installation.*	*Installation (Kilowatts)*	*Percentage of total installation.*	*Installation (Kilowatts)*	*Percentage of total installation*	*TOTAL*	
1948 (First year after independence)	788,393	(55.9%)	515,554	(36.5%)	107,019	(7.6%)	1,410,966	(100%)
1950	1,004,434	(58.6%)	559,285	(32.7%)	140,796	(8.7%)	1,712,515	(100%)
1956 (Last year of First Five Year Plan)	1,596,412	(55.3%)	1,061,441	(36.8%)	228,288	(7.9%)	2,886,141	(100%)

From the above table a few salient points are revealed:—

(*i*) During the twently seven year period (1921-1947) i.e. upto the time of independence. .. Aggregate installed capacity of India increased by about 10 times.
(An average rate of 38.8% increases per year).

(*ii*) During the nine year period (1947-1956) from the date of date of independencde and partition upto the end of the of the First Five Year Plan .. Aggregate installed capacity of India increased by about 2 times.
(An average rate of 23.5% increase per year).

Overall rate of increase (36 years period) .. .. Aggregate installed capacity of India increased by about 22 times.
(An average rate of 61% increase per year)

We are relating these date in comparison to theire relating to other countries.

On 15th of August, 1948 a new 'Organisation for Europeans Economic Co-operation' was formed in Europe, comprising the following member contries:—

Austria, Belgium, Denmark, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, the Netherlands, Norway, Portugal, Sweden, Switzerland Turkey and the United Kingdom.

The organisation was formed to combine their economic strength to join together to make the fullest collective use of their individual capacities and potentialities, to increase their production, develop and modernise their industrial and agricultural equipment, expand their commerce, reduce progressing barriers to trade among themselves, promote full employment and restore or maintain the stability of their economies and general confidence in their national currencies. It is interesting to note that Area and Population figures of this group of European countries are 1.36 million sq.miles and 287.121 millions (1957) respectively, compared to India's 1.24 and 357 million. The Gross National Income of OEEC countries reached 222,350 million Dollars in 1955 while that of India was 208,000 million dollars in 1955-56. While the OEEC group consists of about twelve highly industrial countries, there are countries e. g. Greece, Ireland, Louxembourg, Portugal, Saar, Turkey belonging to the Group that are, nonetheless underdeveloped with regard to their national productivity. This can be well compared with India's industrial sectors, like, Bihar-Bengal, Bombay and Madras-Mysore regions having highly industrial belts and other regions lacking in development. Therefore, a comparison of India with this group of European countries belonging to OEEC should be interesting.

Fuel Resources

Of the probable resources of about 62,636 million metric tons of coal including minor deposits of Brown Coal, peal, lignite etc., utilisable resources of good quality coking coal have been estimated at only 2000 million tons in 1949 rendering it essential to consume this high grade fuel for metallurgical and other important purposes. On the other hand utilisable resources of low grade, non-coking coal are estimated at over 39,650 million tons. There is evidence of exploitable lignite deposit of about 2000 million tons in South Arcot District of Madras. A pilot plant at Neyveli has been set up to examine the commercial exploitation of lignite deposit in the country on a bigger scale.

Hydro Power Resources

Mr. J. L. Mears assessed the hydro electric power potential for the present territory of India at 3.5 million kW. based on maximum continuous flow basis. Assessment of power potential on average flow basis has now been made at 20 million kW. at 100% load factor or 33.3 million kW. at 60% load factor.

OEEC vs India

In the above pages we have discussed the availability of major resources of power in India vis-a-vis other countries. We would now try to follow the general trend of development in O.E.E.C. countries as has been revealed in the study by the Electricity Committee for period 1957-1975. These may be summarised as follows:—

(*i*) Production of electricity in 1956 is 98 per cent higher than the corresponding figure of 1948.

Industrial production in these countries rose by 84 per cent and national income by 52%

India:	Production of Electricity	105%
	Industrial production	43%
	National Income	27.6%

(*ii*) From only 887 in 1950, electricity consumption per capita rose to 1346 kWh in 1956. The corresponding figures for the United States are 2582 kWh and 4095 kWh.

India: 1950 : 10.11 ; 1956 : 20.70
1960—61 : 50 (Planned).

(*iii*) Electricity consumption per unit of national income is very variable among different member countries of the O. E. E. C: less than 1kWh/dollar for Denmark, Greece and Turkey and 6.91 for Norway. The corresponding figure for the United States is 1.58. This can be said to be a measure of utilisation of secondary form of energy in electricity in the bulding up of national Income of a country.

India:— 1956 : 0.029 kWh/dollar

(*iv*) House-hold consumption rose by some 11% in 1956 from the previous year.

India:—Increase of 9.8% from provious year.

(*v*) Estimates suggest that production of elctricity in OEEC countries will increase at an average rate of 7.4 per cent per year. The average increase in thermal electricity is estimated to be 8.5 per cent and in hydro electriciy 5.5. per cent per year.

(*vi*) From the available statistics of different countries it is found that in 'countries which have achieved a stable state of development, the percentage of the national capital resources which are invested in electricity services remains fairly constant and is largely independent of the character of national economy' (agrarian or industrial). It can be said that on an average 6 to 7 per cent of overall national investment is represented by power development, which means that for every crore of rupees spent on developing electricity supplies, some 15/16 crores of rupees are got to be provided to meet the needs of industry and other sectors of national economy.

OEEC: 11.5% : U. S. : 8. to 9%
Pakistan. 18% (Six Year Development Plan).
India : 8% (Second Five Year Plan) (Irrigation & Power 19% .
India : 16.3% (First Five Year Plan).

Therefore, it may be seen that inestment on power development in a developing country like ours is meagre compared to other countries. The effect of of low investment during the Second Five Year Plan is already manifest in many states including West Bengal.

Trend in types of Installation

In this connection it will be interesting to go through the following extract from the eight Enquiry of the Electricity Committee published by the OEEC on trend of production costs:

"(*a*) For hydro energy, in most countries th enew suitable sites for storage or run-of-river plants were the first to be expolited, and the harnessing of additional hydro scheme calls for increasingly ambitious and costly projects. The great strides made in civil engineering have led to appreciable savings in building costs, but have still failed to prevent an increase in the cost per unit of installed capacity .

"(*b*) In the case of thermal capacity, considerable progress has been made in generation technique—however demand, combined with the extension of grid systems, encourages the construction of higher capacity units (100 MW and over) which costs less per kW and which consume less fuel .....

"If all these facts are taken into account, a steady rise in the real costs seems invitable in those countries which rely mainly on hydro power. But the industry in predominantly thermal countries appears to be still improving in efficiency and, despite a foreseeable rise in real costs of fuel, the electricity produced should continue to become cheaper.

"This trend is illustrated by the experiences of last twenty years, the real cost of electricity has fallen by nearly half since 1938 in practically every European country, despite an increase of at least 30 per cent in the price of coal".

In the article "Priorities for Long-term Planning for power", Sarvashree Yadava Mohan & S. Swayambu, of Planning Commission have shown that the picture of planning for power delivery in the twenty five years starting from the beginning of the First Five Year Plan up to the end of the Fifth Five Year Plan would be somewhat like that shown in the following table:—

		At the beginning of the Plan (Million kW)	*Addition during Plan as envisaged (Million kW)*			*Order of Investment of Generator. (Crore Rs.)*		
			Hydro	*Thermal*	*Total*	*Hydro*	*Thermal*	*Total*
1st. Plan	1951-56	204	0.50	0.60	1.0			
2nd. Plan	1956-61	3.4	2.1	1.4	3.5	170	120	290
3rd. Plan	1961-66	6.9	2.5	4.1	6.6	330	370	700
4th. Plan	1966-71	13.5	4.0	6.0	10.0	610	540	1150
5th. Plan	1971-76	23.5	7.0	5.0	12.0	950	450	1400*

* A good part of this investment may be directed to nuclear power if technically and economically feasible.

[*Continued on page* 74

there is a

GOODYEAR HOSE

for every job and a

GOODYEAR CONVEYOR BELT

to carry any material quickly and economically

Long length, low, medium and high pressure suction and delivery hoses for water and oil. Also for air, spray, welding, cement grouting and sand blasting.

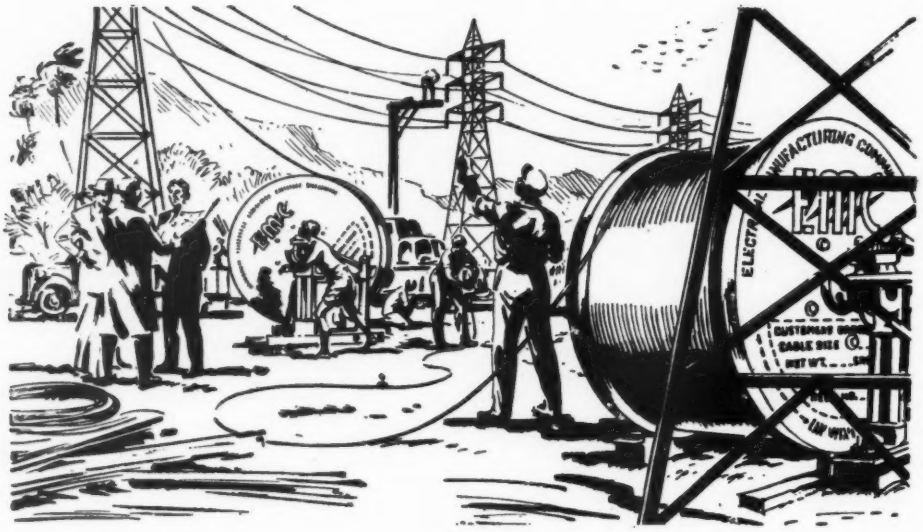
Goodyear Conveyor Belts, by quick transportation of bulk quantities, offer the lowest cost per ton per mile.

GOODYEAR

INDUSTRIAL PRODUCTS DEPARTMENT

60th ANNIVERSARY

PSIP 6



WORKING AT
HIGH TENSION!

We are really on home grounds when it comes to working on High Tension Transmission Lines for carrying huge blocks of power —6,600 volts upwards to 2,20,000 volts—from the generating source to the point of consumption.

Till the other day, the entire material used in transmission lines in India had to be imported. EMC was the first Indian enterprise to enter this specialised field, and within a period of ten years EMC has established itself as the largest manufacturers of transmission line materials in India.

Today EMC not only undertakes the construction of transmission lines — it also manufactures the complete range of equipment required for such projects.

EMC

The largest manufacturers of Transmission Line Equipment in India

136, Jessore Road, Calcutta-28

Representing :

ELECTRICAL MACHINES CORPN. PRIVATE LIMITED
ELECTRICAL MANUFACTURING COMPANY LIMITED

EMC 1048

Super-Grid System for India

By M. HAYATH and V. VENUGOPALAN
Chairman and Director,
Central Water and Power Commission

It is universally recognised that electric power is indispensable to the modern community and the progress of our civilization. The per capita production of electricity is in fact a good index of the economic progress of a country and the standard of living of its people. In India the per capita production of electricity in 1957 was about 28 units per annum as against four-digit figures for Norway, Canada, Sweden U.S.A., and some other advanced countries. Power Supplies are now available in only two per cent of the villages, wherein are living over 80 per cent of our population. The development of our power resources and their transmission and distribution over the widest possible areas are, therefore, of vital importance in accelerating the agricultural and industrial progress of the country. As the coal and hydro power resources are not evenly distributed over this vast sub-continent, it is desirable to evolve plans for a Super-Grid System to reinforce and supplement the regional transmission systems and thereby ensure an even flow of benefits all over the country.

Advantages of Interconnection

The modern trend in advanced countries in power development is towards the construction of super power stations of capacities approaching and even exceeding 1 million kW, closure of small, old or uneconomic power stations, transmission of large blocks of power at voltages exceeding 220 kV to distant load centres, and interconnection of adjacent power systems. A combined hydro and thermal grid system has a greater firm capacity than the sum of the individual systems operating in isolation. In such a combined system, the base load is carried by hydel power during monsoon periods and by thermal power during the dry seasons. The installed capacities of both thermal and hydel power stations are used more effectively, thereby minimising spare generating units and effecting substantial economies in capital cost and maintenance. The frequency and voltage of interconnected systems are less susceptible to variations on account of sudden changes in load and fault conditions than in the case of isolated and small power systems. Key industries can be dispersed and located to suit to the availability of raw materials transport and utilisation. Rural electrification will also be possible on a large scale.

Economics of High Voltage Transmission

The following are the factors governing the economics of high voltage transmission:

(*a*) The load-carrying capacity of a transmission line is proportional to the square of the operating voltage.

(*b*) The transmission line and terminal equipment costs rise rapidly with voltage, but more approaching the first power than the square.

(*c*) As a consequence of items (*a*) and (*b*) the investment cost of transmission decreases as the voltage increases, provided the full capacity of the line can be utilised.

These factors, combined with the economics of Super Power Stations with large-size units, have resulted in significant development of high-voltage long-distance transmission systems in all the advanced countries of the world.

Grid Systems in Other Countries

Before dealing with the transmission systems in India and the plans for the future, it may be interesting to have a broad picture of similar developments that have taken place in other countries. During the past 30 years or so, good progress has been made in this direction in Sweden, U.S.A., Canada, U.K., France, and U. S. S. R. In fact the system interconnections have overflowed the national frontiers in Europe for the purpose of exchanging power to the mutual advantage of the countries concerned. Some of these developments at described below.

Sweden. The hydro power potentials in this country are concentrated in the north while the power demands are mainly in the south. This has necessitated the construction of long-distance transmission lines from

the north to the south. After the completion of six such 220 kV lines between 1936 and 1949, it was found necessary to go in for higher voltage lines. In 1952, a 600 mile long 380 kV single circuit line from Harspranget to Hallsberg was put into service to transmit power to 400 MW. By 1958, the 380 kV network would comprise 1900 miles of lines. As the insulation level of the present 380 kV lines is on the conservative side, the possibility of rasing the voltage of the 380 kV system to the 450-500 kV level, at least in some parts of the system, is being studied by the Swedish engineers. At the same time, investigations are being made concerning the adoption of a higher voltage of transmission. A 650 kV line using four bundled conductors can transmit about 2000 MW with series capacitor compensation. It is considered that two or three 650 kV lines, running from north to south, along with the four 380 kV lines which are expected to be in service by 1960, would be sufficient to transmit the bulk of hydro power which can be harnessed in northern Sweden in the near future. 650 kV may therefore be regarded as the limit for high voltage transmission in Sweden.

United States and Canada: The United States and Canada have extensive transmission system operating at 220-287 kV. The highest voltages in operation are 330 kV in the USA and 345 in Canada. For power development in the western States, the U. S. Bureau of Reclamation envisages a 500 kV grid. The reason why there has not been significant development of super-voltage transmission systems in these countries lies in the fact that the power resources, both hydro and thermal, are not so unevenly distributed in this Continent.

United Kingdom: An extensive 132 kV Grid System has been in operation in this country since the early thirties. In order to meet the growing demand for power, a super-grid at 275 kV has been planned, with some sections designed for eventual operation at 380 kV. In 1955, a double-circuit line running from Staythorpe to Drakelow in the Nottingham area (47 miles in length) was energised at 275 kV. It is envisaged that about 1500 route miles of 275 kV lines would be in operation by 1960.

France: The principal thermal stations are situated in the Parisian region, the collieries in the north and south of France, and the hydro-electric stations in the Alps, Pyrenees and Massif Central. An extensive transmission system has been developed, covering the entire country and interconnecting the hydro and thermal stations. The maximum transmission voltage of 150 kV was stepped up to 225 kV as early as 1925, and by 1938 the French transmission system comprised about 5300 km of 150 kV lines and 2050 km of 225 kV lines. With the increase in load demands and the augmentation of generating capacities, the need for employing a still higher voltage was soon foreseen, and an important trunk line, 405 km long, consisting of two 225 kV circuits, which could eventually be converted into one circuit at 380 kV, was put into operation in 1946. By the end of 1957, the transmission system had about 12,090 circuit km 225 kV system, of which about 2090 circuit km were designed for eventual operation at 380 kV. The operation of the Genissiat-Paris section, 450 km long at 380 kV is reported to have started early in 1958.

U. S. S. R: The highest transmission voltage in operation in Russia is 400 kV (AC). The first stage of a scheme providing for the development by 1960 of a consolidated power system in the European sector of 30,000 MW capacity entails the construction of 5,000 km of 400kV lines with 17 substations, in addition to 500 km of 800 kV (DC) lines. The second stage which would increase the capacity to 50,000 or 60,000 MW, envisages the addition by 1965 of 6,000 to 7,000 km of 400 kV lines and 25 substations. The interconection of power stations in Irkutsch and adjoining districts in the Asiatic sector to operatemas an integrated 400 kV system is also proposed during the same period. One double circuit line from Kuybishev to Moscow at 400 kV (AC) of over 800 km was put into service in 1956. The Stalingrad-Moscow 400 kV double circuit line, 1000 km long, is scheduled for commissioning in 1958-59. Problems of stepping up the 400 kV AC lines now in service to 500 kV and of designing equipment for 600 or 750 kV operation are reported to be under investigation.

Direct Current Transmission

In the field of long distance transmission of large blocks of power, high voltage DC transmission offers certain inherent advantages over AC, and this has prompted a number of countries, notably Russia, Sweden and Switzerland, to carry out extensive investigations on this subject. The main advantages of DC transmission are listed below:

(*a*) Use of two conductors in place of three cuts down capital and maintenance costs;

(*b*) With a given insulation, a greater amount of power can be transmitted with DC by using a higher voltage;

(*c*) DC is free from operational problems associated with line inductance and capacitance.

(*d*) Unlike AC, DC corona does not produce any harmonics causing interference with adjacent telecommunication circuits.

However, there are various problems encountered with DC transmission, such as the availability of suitable conversion equipment and circuit breakers, etc., which are holding up the large-scale employment of DC transmission. Notwithstanding these difficulties, a few advanced countries have put into service some DC transmission lines into commercial operation. A 100 kV DC submarine cable laid in the Baltic sea connecting the mainland of Sweden and the Island of Gotland was put into opertion in 1954, the transmission capacity being 20-40 MW. In Russia, a 200 kV DC line with two single core underground cables is operating over a distance of 67 miles between Moscow and Kashira for transmitting 30 MW.

Although DC high voltage transmission is a comparatively new development, there are promising indications that the adoption of DC will be more economical

than AC for loads of 300-400 MW and above and for distances of 350 miles and above. A 800 kV DC transmission line over a distance of 500 km is under construction from Stalingrad.

Power Expansion Plans in India

The total installed generating capacity, which was about 2.3 million kW at the beginning of the First Five-Year Plan, rose to 3.4 million kW by the end of the Plan period. The Second Five-Year Plan envisages an increase of 3.0 million kW in the installed capacity, bringing the total to 6.4 million kW by 1960-61. It is estimated that it would be necessary to add about 6 million kW during the Third Five-Year Plan period in order to cope with the growing demands of power.

Regional Grid Networks and All-India Grid

At present the highest voltage of transmission in operation in India is 132 kV. As on 31.12.1956, there were nearly 2700 circuit miles of 132 kV transmission lines in service in this country. The 132 double circuit line from Nangal to Delhi (about 200 miles in length) is designed for eventual operation at 220 kV. In addition under the Koyna, Sharavati and Kundah Projects in the States of Bombay, Mysore and Madras respectively, construction of 230 kV lines is scheduled under the Second Five-Year Plan. Sizeable interconnected systems already exist in many States such as Madras, Kerala, Mysore, Andhra Pradesh, Bombay, Punjab, Uttar Pradesh, Bihar and West Bengal. The trend in the various States has been towards the intereconnection of the important generating stations, hydro and thermal, within their regions. However, there has not been any significant expansion of the regional Grids across the State boundaries, except in respect of the Damodar Valley Corporation transmission system which covers Bihar and West Bengal.

Coal and hydro power resources are not evenly distributed over this country. Coal occurs largely in Bihar and West Bengal, and to a little extent in some parts of Central India. Hydro resources are mainly concentrated in the Himalayan region and the Western Ghats, the total power potential which can be economically developed being 40 million kW at 60 per cent load factor. The consumption of power is centered around large industrial cities like Calcutta, Bombay, Madras, Ahmedabad, Kanpur and Banglore. The future pattern of development will be on the lines of making power supplies available over the widest possible areas in this sub-continent. It is in this context that it becomes important to expand the scope of the regional Grids across State boundaries, and thereby evolve in stages an All-India Super-Grid System which will serve as the back-bone of the country's industrial and agricultural development.

The proximity of the regional networks of the four Southern States of Andhra Pradesh, Kerala, Madras and Mysore, and the power imbalance in certain regions, brings to the fore the importance of a co-ordinated operation of the systems by means of suitable interconnections. The 220 kV transmission lines proposed under the Koyna Project in Bombay State may well constitute the beginning of a Super-Grid system in the Western region which may extend beyond the borders of the State towards Mysore in the south and ultimately link up with the Chambal Hydel Project in Madhya Pradesh and Rajasthan. The Punjab-Delhi Grid System may be eventually linked with the Ganga, Sarda and the Rihand Grid Systems in Uttar Pradesh. The D. V. C. hydro-thermal system and the Calcutta thermal system are already interconnected, and this will be extended to cover the Rihand and the Hirakud Systems during the next few years. Side by side with the establishment of these supra-regional Grid systems, an All-India Grid can be developed in stages by means of suitable interconnections.

Super-Grid for the Southern Region

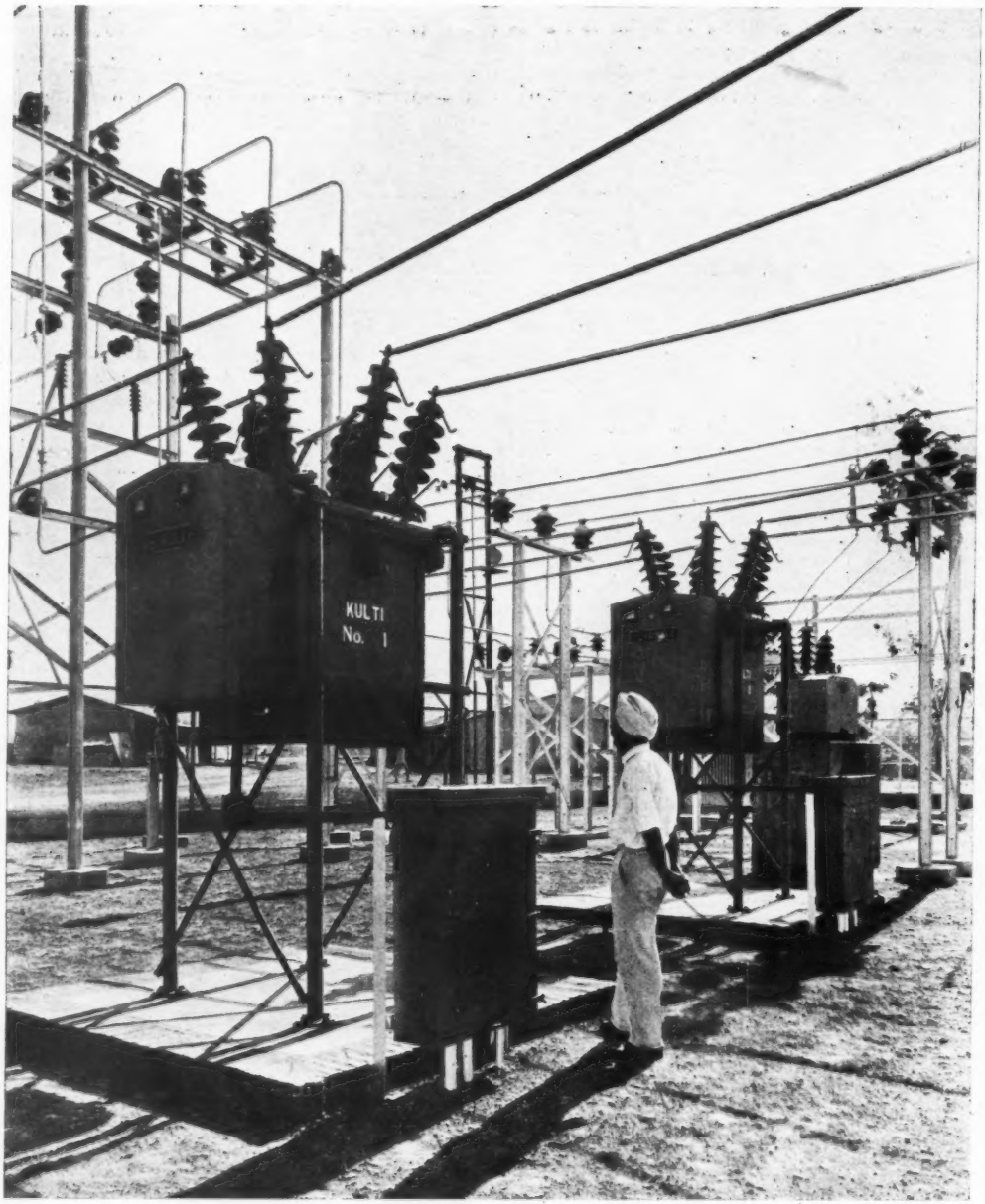
As a first step towards the objective of forming the All-India Grid, a study of the Southern Grid covering the States of Andhra Pradesh, Kerala, Madras and Mysore has been initiated by the Central Water & Power Commission (Power Wing). In the Telangana region of Andhra Pradesh, there is an estimated reserve of about 4042 million tons of coal. This may well serve as a suitable site for a Super-Thermal Station of large capacity for feeding into the Grid System. The hydro resources in this region are largely concentrated in the Western Ghats and in the Godavari river. Some of the major hydro power potentials in this area, *excluding those* that are projected in the Second Five-Year Plan, are given below:

State	*Name of Scheme*	*Power Potential in MW at 60% Load Factor.*
Andhra Pradesh	Siddeswaram	150
	Srisailam	270
	Lower Sileru	300
	Lakshmipuram	310
	Polavaram	172
Kerala	Perumkulam	275
	Arakulam	180
	Chalakudi	148
Madras	Mettur Tunnel	200
Mysore	Barapole	140
	Aghanashini	210
	Kalinadi	646
	Bedtisonda	420
	Jaldurga	280

The utilisation of these hydro power resources can be taken up not only to meet requirements of the States concerned, but also to serve the requirements of the southern region as whole.

Broadly, the Super-Grid will embrace the principal hydro stations and most efficient and large-size thermal stations in the region. The feeding points of the Super-Grid should be capable of absorbing (or exporting under seasonal conditions) loads of the order of 50 MW. Preliminary studies indicate that a transmission voltage higher than 220 kV may be necessary for the major portions of Super-Grid System for the southern region. The necessary studies and collection of data are on hand, and it might be possible to formulate detailed proposals during the Third Fiver Year Plan period for implementation thereafter. There is no reason to doubt that the benefits which will flow from the integrated development of the power resources, backed by a Super-Gird transmission system will more than repay the capital investment.

REYROLLE SWITCHGEAR



REYROLLE TYPE "ORT2" 33000 VOLT SWITCHGEAR AT MAITHON SUB/STN.
AS SUPPLIED TO D. V. C. & OTHER USERS IN INDIA, IN LARGE QUANTITIES

Agents :

BURN & CO., LTD.
CALCUTTA BOMBAY NEW DELHI KANPUR

BOMBAY CO. (PTE.) LTD.
MADRAS & SOUTHERN INDIA

Some Aspects of Power System Design

By H. N. RAMACHANDRA RAO
and B. N.NARAYANA IYENGAR
Department of Electrical Engineering
Indian Institute of Science

Among other things, a proper power system design must ensure that:

(*i*) there is an adequate margin of security against breakdown,

(*ii*) there is reasonable provision for future expansion, and

(*iii*) the cost of construction and operation are a minimum consistent with the above objectives.

As the system consists of generating stations, transformers and transmission lines, each of these must satisfy the above conditions. This paper will confine itself mainly to stress the need for a proper design of the transmission system in the power network. It will be treated under the following heads:

(*i*) Choice of proper voltage
(*ii*) Choice of suitable size of conductor
(*iii*) Effective use of controlled KVAR
(*iv*) Importance of fast relaying
(*v*) Advantages of re-closing circuit breakers.

Choice of Proper Voltage

The transmission voltage is generally fixed by considerations of the amount of power to be transmitted as well as the distance of transmission. The voltage increases with both these quantities and in the very early days a thumb rule of 1 kV per mile was being adopted. In order to standardize power system equipments like transformers, switch-gear etc. it is usual to choose the transmission voltage from a set of recognized standard voltages. Adoption of higher voltage reduces the conductor section but it increases the insulation level, clearance from ground etc. thus increasing the cost of the line. Also higher transmission voltage increases the rupturing capacity of circuit breakers, which increases the cost of terminal equipment. The determination of the best transmission voltage is therefore essentially an economic problem.

The most common transmission voltages in this country are 66 kV, 110 kV and 132 kV, while more recently 220 kV lines are also planned. The more advanced countries like the USA, Uk, USSR and Sweden have adopted voltages between 275 kV and 400 kV. At our present stage of development, there may not be a need for voltages above 220 kV in the immediate future. The curve below shows the trend in transmission voltages during the last 65 years.

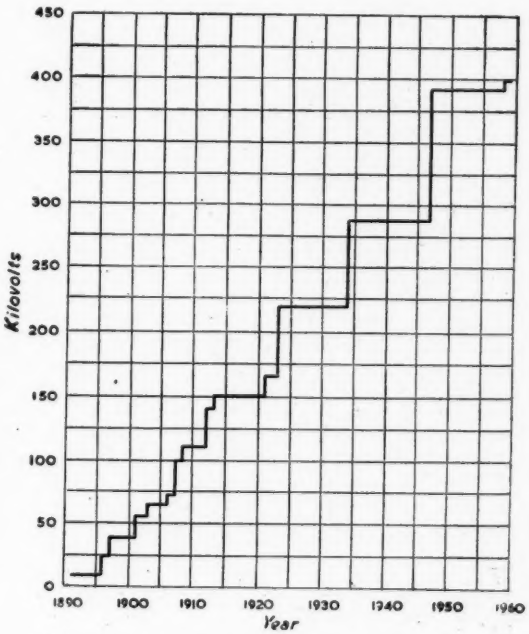


Fig. 1. Trend in transmission voltages in 65 years

66 kV transmission lines have been extensively used in Uttar Pradesh, Madras and in some areas of

Mysore. In Uttar Pradesh these lines were built between 1930-40 to connect in a grid power sttaions of low capacities. But to-day much larger power stations are being built and to carry this power 132 kV lines have been constructed. Loads in areas formerly being supplied from the 66 kV grid have considerably increased and though there is adequate generating capacity in the system, the low transmission voltage of 66 kV restricts the amount of power that may be economically transmitted to these load areas.

In the Madras grid, in the extreme south, a large area is served by 66 kV lines. These lines served their purpose satisfactorily about 25 years ago, but in the present set-up, with heavy loads due to industrial development serious difficulties have arisen in that area. Another contributing factor for these difficulties is the nonavailability of sufficient water during the summer months in the hydro-electric stations and consequent transmission of power from the thermal station situated far away.

In Mysore also where the first hydro-electric project was constructed, 66 kV was the transmission voltage. Even with the coming in of the Jog Hydro-electric Scheme some years ago and the 110 kV transmission lines connected with it, there are certain areas still served by 66 kV lines. The load in these areas is rapidly increasing and it has become a serious problem to the power supply authorities to ensure satisfactory service to these consumers.

Consideration in maintaining the stability of a power system under probable conditions of fault also lead us to the conclusion that under present conditions, 66 kV for power transmission is on the low side. It can at best be used for long distance radial feeders if the loads demand it. The surge impedance loading for a 66 kV line is about 11 mW and if the line is properly regulated it may be possible to transmit about 15 mW on a single circuit economically.

This leaves us with the two common transmission voltages 110 kV and 132 kV in this country. While the former is in extensive use in Bombay, Mysore and Madras, the latter is practically the voltage employed in the entire North where development is comparatively more recent. The Tata Hydro System operating in a restricted area has 110 kV transmission and the operation is perfectly satisfactory as most of the load is concentrated in and around Bombay. When the Koyna Project comes into existence, large block of power (240 mW) will have to be transmitted over 150 miles and so 220 kV has been considered necessary.

In the Madras grid 110 kV is used over a large area. With the coming in of Kundah, Periyar and possibly Neiveli large amount of power will be available and though some of the big load centres may develop close to these stations, there would still be need for proper transmission facilities to carry power one way or the other under varying generating conditions. This has led to the serious consideration of linking these stations with 220 kV transmission system.

Double circuit 132 kV lines form a big ring in the DVC system. This is of very recent construction and the system is still developing. When 132 kV was chosen as the transmission voltage and in addition double circuit was provided, it was thought that there had been adequate provision for any forseeable development. But within 10 years of its existence rapid development have taken place as to need a revision of that opinion. When Bokaro Thermal Station with a capacity of 220 mW was designed, it was one of the biggest power stations of the country. Since then equally big stations have come into existence or will soon be commissioned. Even in DVC, further development is expected to be on the lines of building super power stations near the pit heads of coal mines. 132 kV lines can hardly be expected to carry such huge quantities of power from these stations to the industrial centres and so the DVC authorities have started thinking in terms of 220 kV lines to interconnect the projected power stations to the existing system.

In Mysore, Sharavati Valley Project with a potential of 600-700 mW, needs at least 220 kV transmission system for transferring power over about 250 miles.

As visualized to-day, the probability of building large capacity power stations in India is greater and the choice of proper transmission voltage assumes great importance. There is also the possibility of forming regional grids in which case voltages above 220 kV would perhaps be necessary.

Interposition of too many transformers for interconnections between different voltage systems is not good practice as the increased reactance between the power sources restricts the power transfer. Based on all these facts, it is necessary that the system design engineer should ask himself the question what is the highest voltage I can use consistent with economy, load, and probable future growth?' rather than the question 'what is the lowest voltage at which I can economically transmit the required power?'. It is not denied that at times there are compelling reasons to compromise with what may not be technically very sound but viewed as normal policy it is desirable to look a few years ahead.

A comparison of two or more voltages for transmission to determine the most suitable one involves consideration of three factors.

(*i*) Comparative costs
(*ii*) Comparative reliability
(*iii*) Comparative right-of-way requirements from the standpoints of land usage and availability.

Regarding costs, they consist of annual charges on investment in transmission lines and sub-station equipment, annual I^2R losses and annual charges on investment for reactive kVA supply. Operation and maintenance costs are usually small relative to the other costs. In this country comparison will have to be between 110 kV (or 132 kV) and 220 kV. Before comparing costs, suitable plans for both transmission voltages must be formulated. It is necessary that the

number of 220 kV sub-stations in the load areas be held to a minimum and connected by 110 kV ties to smaller substations in the area. Consideration must also be given to the selection of an optimum transmission line design for each voltage. The minimum number of lines required to satisfy established voltage regulation, transient stability and reliability criteria is to be determined.

From the point of view of reliability, it may appear that the use of larger number of 110 kV circuits has more advantages than the necessarily smaller number of 220 kV circuits, introducing greater reliability an operating flexibility. But modern methods of construction permit us now to build practically lightning-proof 220 kV transmission lines, thus dispensing with the need for duplicate lines for the sole purpose of reliability. Therefore the differences between 200 kV and 110 kV from the point of view of reliability lend to disappear.

The right-of-way requirements for 220 kV and 110 kV transmission are a function of the number of circuits needed and the space occupied per circuit in each case; the number of circuits in turn depends on the permissible loading per circuit at each voltage. The theree factors which limit the loading are (i) thermal capacity (ii) voltage regulation and (iii) transient stability.

Considering the thermal capacity limitation, the inherent advantage of the higher voltage is indicated by the direct ratio of the voltages i.e. 2 or twice as many 110 kV circuits will be required to carry the same kVA as a given number of 220 kV circuits, assuming equal current carrying capacity conductors in both cases.

Voltage regulation limitation, being basically a function of impedance, indicates that the advantage of the higher voltage is in proportion to square of the voltage ratio i.e. $(\frac{220}{110})^2 = 4$, which means that one 220 kV circuit is equivalent to four 110 kV circuits.

Though it is difficult to draw a similar comparison for transient stability limitation as it depends on many extraneous factors, it may be taken that the ratio of comparative stability approaches the square of the voltage ratio i.e. 4: 1 for 220 kV and 110 kV circuits.

While the above can be taken as a rough guide, a study of the proposed application will soon indicate which limitation is dominant; at short distances, thermal capacity is likely to be the limiting factor while for longer distances voltage regulation and transient stability may be the limiting factors. From a long range point of view, maximum utilization of available right-of-way may be of great importance and as the number of structures may be more significant rather than the right-of-way width, 220 kV may be preferable to 110 kV.

Choice of Conductor Size

Copper and ACSR are the two conductors which are in use today, and it is possible that at the higher voltages of transmission ACSR will be exclusively used. Since the cost of conductor material forms a good proportion of the total cost of transmission, there is a natural tendency to be economical and use smaller sections. There are many cases where small leads are situated at quite a distance from the power system but there may be good reasons—sometimes non-technical — to supply the load by 66 kV line. Naturally the smallest size of conductor that can carry that load without undue voltage drop will be chosen. In a rapidly developing country like ours, one cannot be too certain of load growth though in recent years systematic load surveys are being made. It is, therefore, necessary that in the choice of conductor size possible future growth is kept in view. Apart from this, it is necessary to keep down the Ohmic resistance of the conductor in order to have an efficient system with good voltage regulation. We have come across many instances in the case of 66 kV lines and a few instances in the case of 110 kV lines where the ratio r/x i.e. resistance per mile to reactance per mile was equal to or greater than 1. In our view this ratio should correspond to the following values depending on the transmission voltage:

66 kV lines	r/x = 0.50
110 kV ,,	r/x = 0.40
132 kV ,,	r/x = 0.35
220 kV ,,	r/x = 0.20

Based on these values the conductor sizes to be used (for normal spacing) would be:

66 kV	lines	0.10 sq. in. equivalent copper
110 kV	,,	0.10 — 0.15 ,,
132 kV	,,	0.15 — 0.20 ,,
220 kV	,,	0.30 — 0.40 ,,

At higher voltages, the size of the conductor is determined by considerations of corona etc. The feasibility of using bundle conductors (which reduces effective reactance as well as corona loss) may have to be examined at voltages higher than 220 kV.

Effective Use of Controlled kVAR

One of the most important considerations in the design of a power system is voltage regulation at the various sub-stations. The drop in voltage between the sending and receiving ends is due mainly to the reactive kVA requirements of the load and the reactance of the line. This can be more clearly expressed as follows:

The loads in a power system are mostly inductive i.e. they absorb lagging reactive kVA; the transformers and transmission lines have a large reactance and whenever current flows through them reactive kVA is absorbed. In addition there is a voltage drop which is proportional to the reactive kVA requirements at the receiving end. These reactive kVA requirements are met by generators, transmission line capacitance and by synchronous or static condensers if installed in the system. It may be stated at once that it is impossible for the generators alone to supply all the lagging reactive kVA requirements in a large power system with long transmission lines; for

even if low power factor generators (which are expensive) are available in the system, to transmit the lagging reactive kVA a large difference in voltage levels between the sending and receiving end h.v. buses would be required. Low reactance lines of high voltage are ofcourse helpful in that $I^2 \times$ losses are reduced while the charging kVA (leading) is considerably increased. But the most satisfactory method of supplying the reactive kVA as well as of voltage regulation is by the use of static capacitors or synchronous condensers. While static capacitors have the advantage that they do not need attention, they suffer from the serious disadvantage that their corrective capacity is least when it is most required and vice versa. For proper operation, automatic methods to switch them in and out would have to be provided, and this would make them very expensive. In addition there are also possibilities of series resonance.

Synchronous condensers on the other hand have many advantages, though they require continuous attention. A synchronous condenser has this superiority over a static capacitor in that it can regulate the voltage under all conditions—raise it when it is low and lower it when it is high. This is because, the synchronous condenser can operate on leading or lagging power factor depending on its excitation. A proper distribution of synchronous condensers in the system capable of supplying reactive kVA at locations where it is actually required makes the transmission system highly efficient. This permits the use of high power factor generators (0.9—0.95) in the system making them less expensive and also utilization of the transmission system for carrying more and more wattful power.

It is sometimes imagined that the problem of voltage regulation can be solved by the provision of suitable taps on transformers. The real solution to voltage regulation is the pumping in of reactive kVA into the system. A transformer is not a source of reactive kVA; all that can be accomplished by operating the taps on a transformer is a re-distribution of the flow of reactive kVA in the system. Therefore while a transformer with on-load taps is a very useful equipment for voltage regulation in a system, with controlled reactive kVA injected into it at suitable points, such a transformer is incapable of stisfactory operation when the system reactive kVA requirements are not properly met.

The table below gives the approximate relation between the delivered kW, and kVAR required for various transmission distances at different transmission voltages.

The table indicates, for example, that while for transmitting 120 mW over 300 miles of 220 kV circuit no corrective reactive kVA for the line need be supplied, to transmit 240 mW over only 100 miles of 220 kV circuit 96 mVAR is to be supplied as corrective reactive kVA for the line alone and if the power transmitted is increased to 360 mW, the line requires 270 mVAR. This reactive is exclusive of what may be required for the loads. The study of the problem of kVAR supply

Table 1

Approximate surge impedance loading per circuit

kV	*Delivered kW* $2.5\ KV^2\ (P_s)$	*kVAR required* (Q_L)	*Length of Transmission line*	$\frac{Q_L}{P_s}$
220	120 mW	0	300 Miles	0
132	44 ,,	0	300 ,,	0
110	30 ,,	0	300 ,,	0
	Delivered Power $5.0\ kV^2\ (P_s)$			
220	240 mW	96 mVAR	100 Miles	0.4
132	88 ,,	35 ,,	100 ,,	0.4
110	60 ,,	24 ,,	100 ,,	0.4
	Delivered Power $7.5\ kV^2\ (P_s)$			
220	360 mW	270 mVAR	100 Miles	0.75
132	132 ,,	99 ,,	100 ,,	0.75
110	90 ,,	67.5 ,,	100 ,,	0.75

has led to the following results which may be used as guides for economical design of transmission systems:

(*i*) Increase in either kW loading or transmission distance markedly reduce economic kVAR transmission from the generating stations.

(*ii*) Even for moderate distances an economic kVAR supply pattern in many cases dictates substantial kVAR support at the receiving system, so that kVAR delivered to the load bus from the generator are actually negative.

(*iii*) Load tap changing equipment on a medium or heavily loaded transmission system is seldom economically justified merely for increasing load area kVAR supply from the generating station.

(*iv*) Optimum kVAR transfer for normal system conditions dictates high receiving system voltages for loadings and distances where system stability considerations become important. Thus proper planning for normal operation is consistently in the direction of improving emergency performance.

Importance of Fast Relaying

An important consideration in the design of modern interconnected power systems is that of transient stability as an interruption of service may lead to serious consequences. Most common among the causes that contribute to transient conditions are faults on the system like a flashover from line-to-ground, line-to-line, line-to-line-to-ground or all lines to ground. Of these some types are more common than others, and an economic design of the system can be made only for maintaining stability under the most probable types of faults. Among other things the ability of a system to remain in synchronism when a transient fault occurs depends to a large extent on the rapidity with which the fault is cleared. The transient stability power limit a of power system depends on the

system reactance, inertia of the machines, the type of fault and the duration of the fault. The curves below give a general indication of the power limits against fault duration for various types of faults, assuming that the other factors are constant.

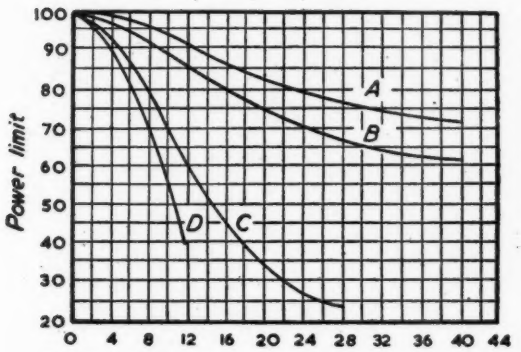


Fig. 2 Effect of duration of fault on power limits for different kinds of faults.

A – L-G Fault *C – L-L-G Fault*
B – L-L Fault *D – 3 Phase fault*

Single line-to-ground faults are the least severe and if isolated fast enough, the system can operate at a large power limit for transient stability. Three phase faults are the most severe and if the fault is not isolated very fast, instability might result, so much so that with the type of relays and circuit-breakers in use prior to 1929, the power limit for three-phase fault was almost negligible. Fortunately statistics shows that single line to ground faults are the most common while three-phase faults are very rare. Modern circuit-breakers and relays also operate very fast—the fastest clearance taking only 3 cycles—and when these are used in the system, it can operate at a high stability power limit. Circuit-breakers taking more than 8 cycles for operation are rarely used in modern interconnected systems and if the price of such breakers are taken as standard then, 5-cycle breakers cost about 15 per cent more while 3-cycle breakers cost 40 per cent more. Power system studies have conclusively stressed the imperative need for using fast relays and circuit-breakers to hold a large interconnected system in synchronism under conditions of transient faults.

If pilot wire or carrier current is not used for relay operation, there would be sequential tripping of the circuit-breakers at the ends of a faulted line; this has the same effect as a delay in operation of the circuit-breakers. Therefore to make effective use of the available fast relays and circuit-breakers carrier current protection is being used increasingly. The high speed impedance relay which is now commonly employed operates in 1-3 cycles for a fault in its own zone.

With the growing size of our systems and with the inevitable long transmission distances, it would be more economical to operate at relatively close to stability limits by providing fast relaying and high-speed circuit-breakers rather than operating at lower power limits due to lack of high speed relays and circuit-breakers.

Reclosing Circuit-Breakers

If provision has been made in the system for fast clearing of faults, then further advantages may be gained by the installation of reclosing circuit-breakers. Two fundamental considerations that arise in connection with this problem are:

(*i*) the maximum permissible time for de-energization of the faulted circuit without loss of synchronism.

(*ii*) minimum permissible time for de-ionization of the fault arc.

The first one can be determined by analysis; it naturally depends on many factors like the system arrangement, load on the system at the time of fault, the type and location of fault etc. The second consideration cannot however be so easily determined. And the information available on the de-ionization time of fault arc is very meagre. However, tests have indicated that 6-9 cycles for 3-phase clearing and 12 cycles for re-energizing result in about 90 per cent successful operation at 132 kV.

An improvement on the 3-phase reclosing breaker is the single pole reclosing breakers. It is well-known that if one phase of a transmission line is opened, some amount of power can still be transmitted over the remaining phases and therefore in the event of a fault on one line, the system disturbance is minimized. Most line interruptions are due to flash-overs, which must be isolated to put out the arc. Thus it is usually permissible to reclose the faulty line and restore the system to its original condition without at any time reducing the power limits to as low a value as would be the case if all three-phases were disconnected. The curves below give a comparative idea as to the permissible transmitted power and reclosing time for clearing one line to ground fault and maintaining stability with 3-pole and single-pole reclosing breakers.

With single-phase switching, the arc on the faulted conductors after the line breakers have opened, tends to be maintained by the capacitive coupling with the sound phase or phases; longer times therefore may be required for de-ionisation of the arc path in a single-pole switching.

The optimum time for de-energization is not necessarily fixed but varies with system condition. If the stability margins are small, it would be justifiable to decrease the de-energization time while longer time could be allowed if there is large stability margin. In fact, if the system has many parallel lines, reclosing may not be necessary at all and if there is only a single circuit tie, high-speed reclosing may be essential. In between these extreme cases there exist many conditions where high-speed reclosing may be used with advantage.

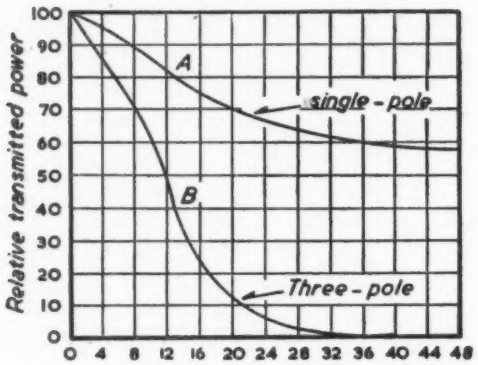


Fig. 3

A – Three-pole reclosing breaker, 4-cycle opening time.

B – Single-pole reclosing breaker, 4 to 10 -cycle opening time.

Network Analyzer studies may be made to determine the maximum permissible time for de-energization of the faulted circuit and such studies form an essential part of the engineering analysis of the feasibility and desired characteristics of reclosing equipment for the particular system under consideration:

Results of transient stability studies show:

(*i*) That the benefits to be obtained from reclosing are greatest for single circuit lines or simultaneous faults on double circuit lines.

(*ii*) That three-phase reclosing is a very practical means for maintaining the transmission loading between interconnected areas having generation capacities of the order of at least four times the transmission line loading.

(*iii*) That with three-phase reclosing of single-circuit lines, a decrease in the clearing time for three-phase faults is as important as a decrease in de-energization time.

(*iv*) That with parallel circuits, the benefits from reclosing breakers decrease with decrease in line length and with increase in the number of intermediate switching stations.

(*v*) Single phase switching provides increases in transient power limits on single circuit lines for single line-to-ground faults, which are not possible with three-phase switching. The differences, however, may be small if the interconnected areas have large generating capacity relative to the power transmitted. In other words, if the inertia constants of the interconnected systems are sufficiently great, the practical advantages of single-phase switching may be negligible.

(*vi*) For single line-to-ground faults, if single-pole switching is used, the time for de-energization is not particularly critical as regards its effects on the stability limits, and therefore it is not necessary to strive for low reclosing time as is the case with three-phase reclosing.

(*vii*) The advantage of single-pole switching appears to be important only when reclosing is used on single circuit interconnecting lines when the generating capacity of one of the interconnected areas is not much greater than the load which must be transmitted.

(*viii*) Single-pole switching appears to offer no advantage over three-phase switching for faults involving more than one phase.

Finally, high-speed reclosing involves the risk that occasionally the fault may not be self-clearing and any attempt to reclose may do harm rather than good. This risk may be evaluated in two ways—first, the decrease in power limit due to unsuccessful reclosure below that obtained with no reclosure and second, the decrease in power limit due to an unsuccessful reclosure below that obtained with successful reclosing. Calculations indicate that:

(*i*) For double rcircuit lines, single-phase switching and reclosing of single line-to-ground faults can involve negligible risk of either the first or second kind.

(*ii*) Automatic three-phase unsuccessful reclosure against single line-to-ground faults involves negligible risk of the first kind but appreciable risk of the second kind.

(*iii*) For either single-phase or three-phase unsuccessful reclosure against the more severe faults (double line-to-ground or three-phase), the risk of both the first and second kinds is appreciable.

(*iv*) In general it may be said that the risks are least where the possible gain from reclosing is greatest.

In conclusion, it must be stated that provision of fast relays and circuit-breakers, and of single-pole or three-phase reclosing breakers on important tie lines are some of the methods by which the system can be operated at high stability limit without the necessity of duplicating long high voltage transmission lines.

Test on 220 kV Transmission Line Tower

By G. R. HUKMANI
Chief Design Engineer
Kamani Engineering Corporation Ltd.

The testing of a Transmission Line Tower can be well said to be an integral part of the design of the tower. The design of tower has to be based on various emperical assumptions which are progressively modified and evolved with view to achieve greater discriminating and economical use of steel sections and at the same time ensure that it will not entail any reduction in the strength and stability of the structures.

The testing of the tower therefore becomes an essential feature of great technical significance not only to designers but also to the users and it became even more so in the case of the tower designed for an important line of Koyna Hydro-Electric Project where for the first time 220 kilovolts has been adopted for transmitting power from Koyna Generating Station to the City of Bombay. The line is spread over a stretch of 150 miles through the most difficult terrain of Western Ghats, which indeed makes it a landmark in the history of power transmission in India.

Test on straight line tower designed for this line was held on 22nd November 1958 which quite naturally created a wide interest among the transmission line engineers all over India.

The tower as tested is generally outlined in figures 2, 3 & 4 and fig. 1 and table 1 give technical data forming the basis of design.

Testing station where this test was carried out is operated by M/s. Kamani Engineering Corporation Ltd. at their Kurla Works since 1951 and provides all the basic facilities for conducting tower tests, such as

- — a permanent test bed capable to stand overturning of 4000 tons feet and having adjustable fixing arrangement to take towers of any base width upto 25 feet;
- — anchorage of guyed masts on transverse and longitudinal sides to guide the wire ropes pulling the tower under test;
- — winches for mechanical application of loads;
- — hydraulic dynamometers for measuring the loads accurately;
- — scales and instruments required for recording the deflection of the tower under various loading conditions.

The testing station is thus well equipped, but it was not without considerable amount of additional arrangements that this test on 220 kV tower could be carried out at this station. Apart from renewing some old guy wires and their anchorages etc. and providing additional guys and compound pulley block systems to decrease the load on the structures of the station, the manner in which the different combinations of various loads were worked out and actual design conditions were created was indeed an ingenious achievement.

Transverse and Vertical Loading

Height of the transverse mast being much shorter than the actual height of the tower under test, it was not possible to apply horizontally the transverse loads representing wind on the conductors, wind on the steel structure and small components of wire tensions. This difficulty was overcome by combining the transverse loads with portion of vertical loads thereby changing the direction of loading along the resultant inclination (Fig. 2) This incidentally helped relieving the transverse mast from extra thrust.

Balance vertical loads were applied by means of crates loaded with standard weights suspended at each conductor point.

Longitudinal Loading

It proved comparatively a hard task to determine a suitable manner for applying the longitudinal loads in Broken Wire Conditions, without overstressing any component of the tower.

Topmost pulley available on the longitudinal mast was 21'-3" below the top cross arm and 37 ft. below the Ground Wire peak of the tower. Applica-

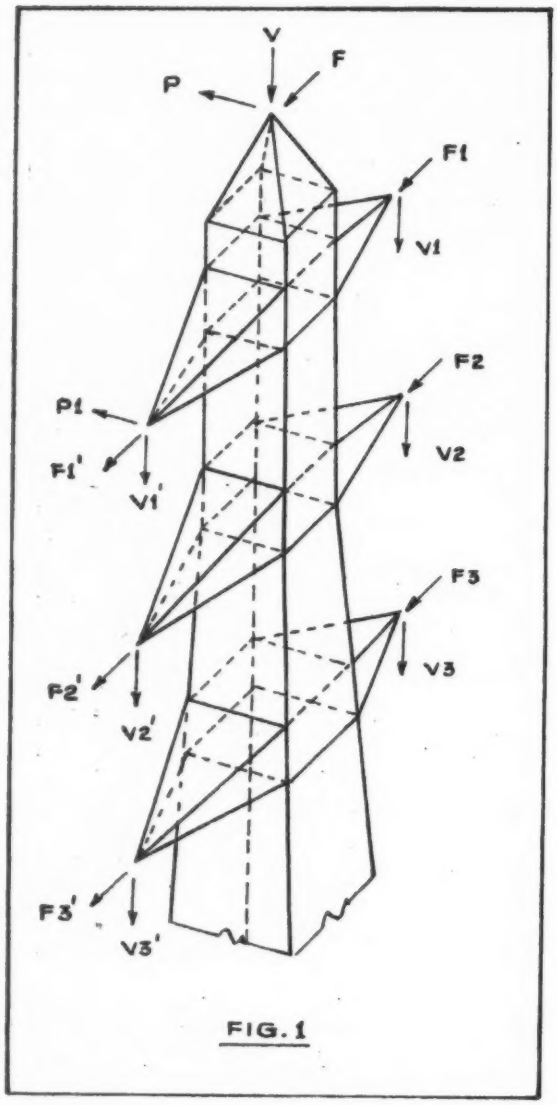


FIG. 1

tion of loads along such steep inclination gave rise to very high vertical components which needed proper compensating as otherwise additional unbalancing at top cross arm level, as indicated by the calculations, was going to overstress some of the leg members beyond the yield point. Solution to this problem was found by adding extra weights on the unbroken wire side of top cross arm to counter-balance the additional unbalancing effect. The increased vertical loads resulting from the above arrangement were compensated by reducing dead weights at the peak and other cross arm levels.

Loading of ground wire peak presented a much more complicated problem. Tower members severely affected in this case being the peak members themselves and the leg members immediately below the peak, it was not possible to compensate for the overloads at other levels of loading below these critical parts. Various alternatives including the proposition for separately testing the straight portion of the tower right from hamper up to the peak were considered but not found acceptable for one or the other reason. Finally it was decided to work out backwards from the maximum stress figures of the severely affected members and find out a single equivalent pull at ground wire level which would represent the required longitudinal, transverse and vertical loads.

A very adequate solution correctly representing the design conditions was found out in the following manner:

Single equivalent pull in the wire at ground wire peak was assumed as X. Angles of inclinations being known as in Fig. 3 and 4, the components of this pull in three different directions could be expressed as

Vertical component X Cos A
Longitudinal component X Sin A. Cos B
Transverse component X Sin A. Sin B

Stresses due to these loads in the critical members were calculated in terms of unknown factor X, and the same were equated to the actual design stresses and two values of X were obtained. These two values were practically equal and therefore selection of equivalent load did not involve any rechecking.

Table I

Design Data

Voltage	220 kV
No. of Circuits	2
Allowable Deviation	2 degrees
Normal Span	1050 ft.
Max. Sag in still wind at 130°F	22 ft.
Wind Pressure	20 lbs./sq. ft.
Ground Wire	19/12 SWG 45 tons quality Max. safe tension 5720 lbs.
Line Conductor	30/0. 157 Al + 7/0.157 steel Max. safe tension 12200 lbs.
Factor of Safety	2.5 in Normal Condition 1.5 in Broken Wire Condition either G. W. or one Top Conductor broken.

Design Loads

Loads	*N. C.*	*B. W. C.*	*Loads*	*N. C.*	*B. W. C.*
V	1300	1000	P1	—	9150
V1	2700	—	F	806	403
V1′	2700	200	F1	2207	—
V2	2700	—	F1′	2207	1354
V2′	2700	—	F2	2207	—
V3	2700	—	F2′	2207	—
V3′	2700	—	F3	2207	—
P	—	5720	F3′	2207	—

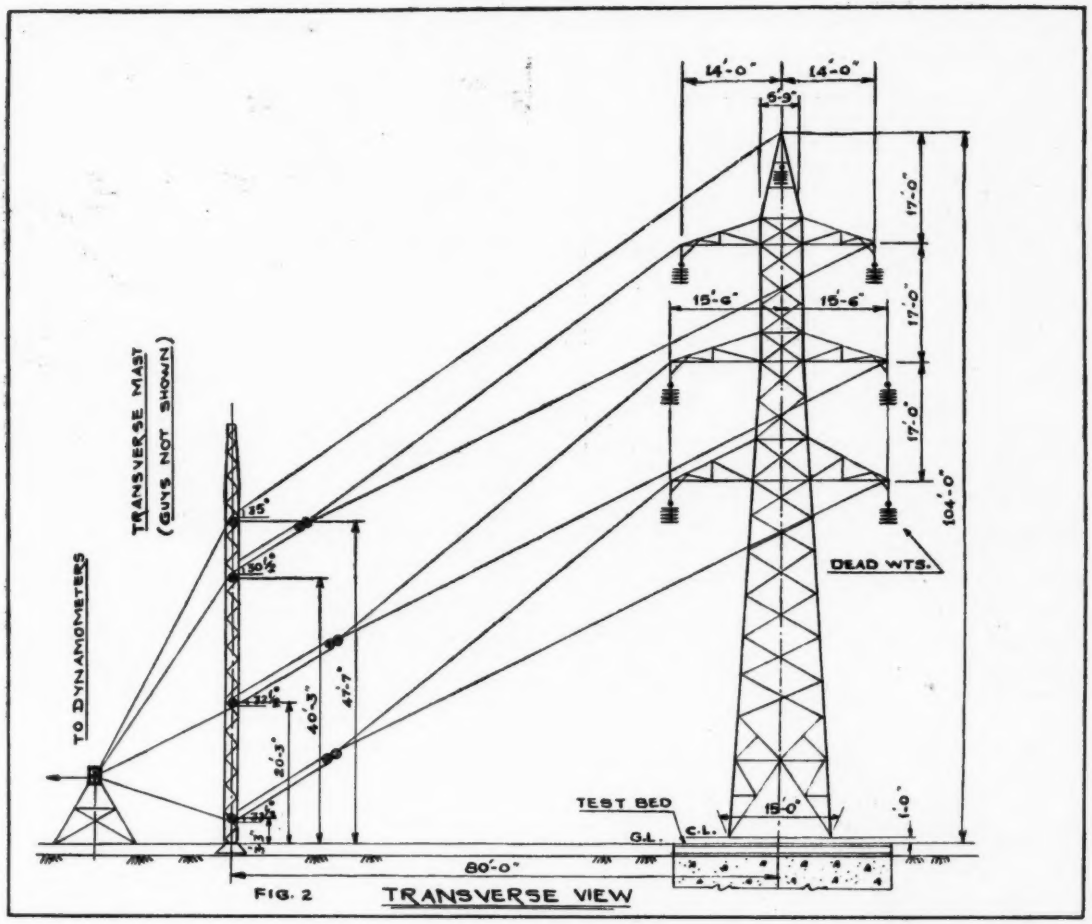


FIG. 2

Another difficulty encountered was in attaching the wire ropes with the tower peak due to oblique position of the equivalent pull. Gap between the two of the peak members was hardly 1½ inches and wire taken in between them was going to exert pressure on one of the legs, when tought. This was definitely not desirable and therefore it required modification of cap design and use of thin wire loop to get a sound connection for the pulling rope without causing any eccentricity of loading.

Project engineers and designers of the firm worked together for several days to finalise all the adjustments and also to carry out minute preliminary checks.

Checks carried out

For ensuring thoroughness in the entire working, following checks were carried out jointly by the engineers of the Purchaser and the Firm before the test commenced:

(*a*) All dimensions like overall height, vertical separation between the cross arms and their horizontal spread and tower widths at the top and bottom of the tower as also the sizes and sections of all the components were properly checked and found in order.

(*b*) Pulley positions and various other distances of importance were measured and tallied with the test data sheet.

(*c*) All dynamometers were caliberated and the results plotted for ready guidance.

(*d*) Verticality of the tower was also examined with the help of techometer.

Tests Conducted

In accordance with the stipulations of the purchasers specification following tests were carried out in the order indicated:

Normal Condition Test:

Test No. 1 — with 150% of design load
,, 2 — with 175% of design load
,, 3 — with 200% of design load
4 — with 225% of design load
,, 5 — with 250% of design load

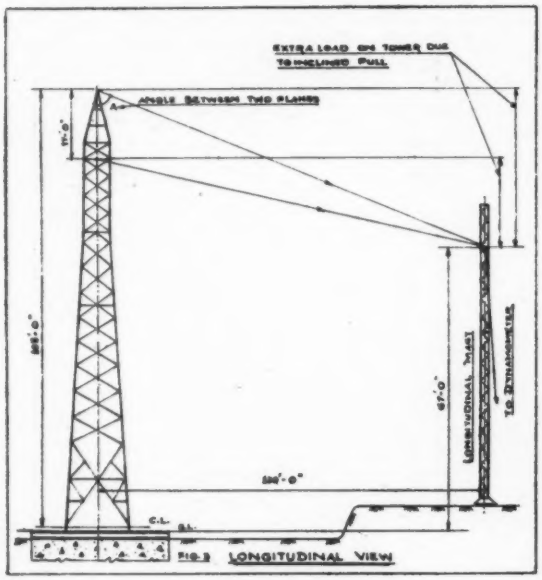


FIG 3 LONGITUDINAL VIEW

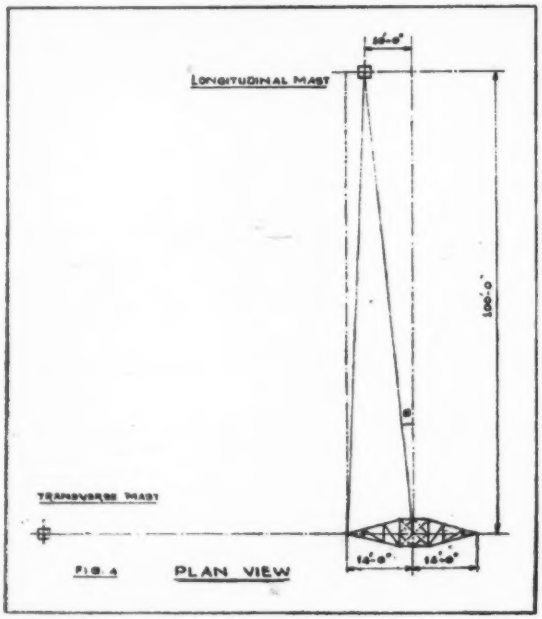


FIG 4 PLAN VIEW

Broken Wire Condition Test:

Test No. 6— For Ground Wire Broken Condition with 150% of design load

" 7— For Top Conductor Broken Condition with 150% of design load.

Test to Destruction:

Test No. 8— Test to destruction was carried out by increasing the loads in steps of 12.5% beyond the loads under Test No. 5 upto the point of yielding. Tower yielded while the loads were being increased to 325%, that is, approximately at 320% of the design loads.

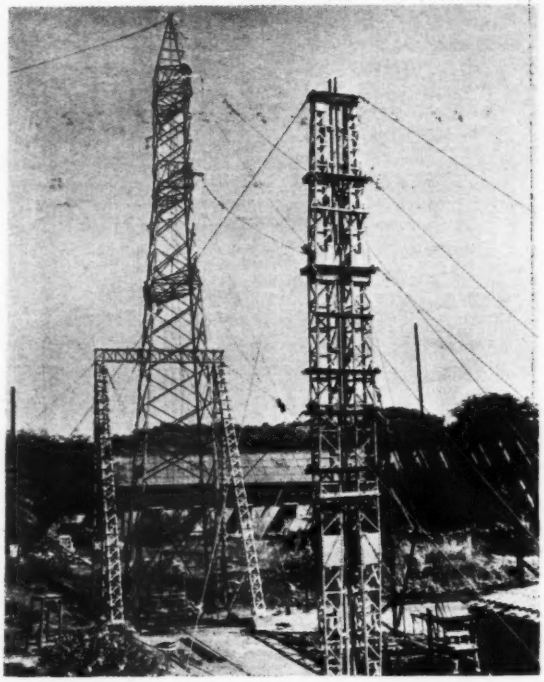


Photo 1. Phototype model tower on Test Bed before commencement of test.

Results

Results of the test were remarkably satisfactory which indicate the progress achieved by our country in acquiring full know-how about this specialised line of design which has remained quite unknown to this land prior to independance.

Tower under test behaved exactly in accordance to our predictions and yielding under the destruction test also took place exactly at the location predetermined by design calculations.

As anticipated, the leg members in the second part (counting from bottom) buckled about its square axis of gyration.

Tower design has been based on the following strut formula for steel conforming to B. S. S. 15.

45000—190 L/R lbs. /sq. in. for L/R upto 150
36000—130 L/R lbs./sq. in. for L/R 150 to 200

Test results revealed that the critical leg member which according to design calculation was to stand a

Photo 2. Yielded portion of the tower after completion of destruction test.

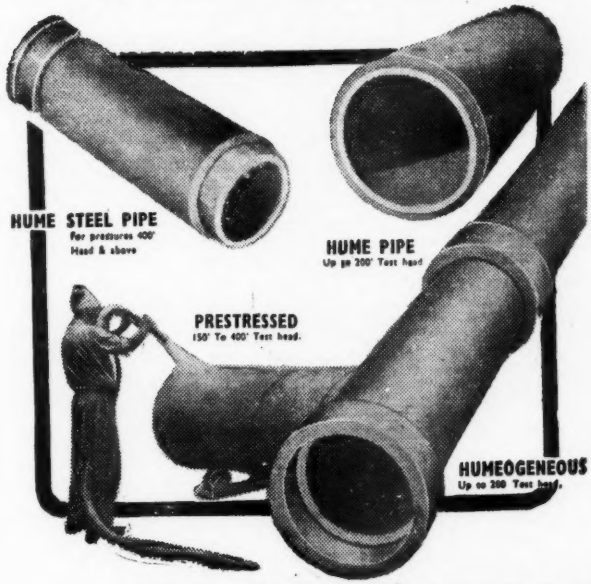
compressive stress of 96,500 lbs. could actually stand a stress upto 108,000 lbs. (i.e. approximately 12% extra stress) before yielding.

These results were quite in line with the results of previous tests carried out on towers designed on the basis of same strut formula. All tests have indicated that if the detailing work is done with proper care so that all unwanted eccentricity in the joints are minimised the compression members designed on the above formula would stand very comfortably the utlimate design loads with latent capacity to stand loads further up by 10% atleast.

Deflection recorded at 90 feet height of the tower under various conditions of loading were as under:

Elestic Deflection under 250% load (N.C)—6.0 inches
Permanent set with loads released —Negligible
Elastic twist under 150% load (B.W.C)—0.8 inch
Permanent twist with loads released —Negligible
Deviation from verticality including bolt slip with loads released —1½ inches
Allowable deviation from verticality for 90 feet height is — 3 inches

HUME PIPES
FOR EVERY REQUIREMENT



i) Hume Pipes are ideal for Railway and Road Culverts, drainage, irrigation and water supply mains.

ii) Humeogeneous pipes are better quality of Hume Pipes, where Electrically welded Steel Cages and Drymixed concrete with minimum water is used to give better consistency and strength.

iii) Prestressed Concrete Pipes are economical with ability to withstand high pressure.

iv) Steel Pipes are best for waterworks where Test pressures of 400′ head and above are required.

THE INDIAN HUME PIPE CO. LTD.
H. O. CONSTRUCTION HOUSE, BALLARD ESTATE, BOMBAY—1.
Calcutta Branch : 190/1, Rash Behari Avenue, Calcutta—29.

Continued from page 58]

Power Development in India

The author agrees with Sarvashree Yadava Mohan and Swayambu that the power demand of next ten years will have to be met primarily by thermal installations, as it is doubtful whether substantial hydro capacity would be available by then.

It will, however, be necessary to take up the work of survey and investigation of a number of important hydro stations distributed all over the country so as to ascertain which of these projects could be economically implemented. Normally, cost per kilowatt installed in a hydel project varies from Rs. 1000 to Rs. 2000, that of a thermal plant may be estimated at Rs. 800 to Rs. 1000 whereas cost of a nuclear plant may be estimated at Rs. 2000 per kilowatt. Latest figure available from the British Electricity Council indicates that nuclear power station could be built at one and a half times the cost of a conventional thermal plant.

Per Capita Consumption & Installed Capacity

Let us now discuss about the present backwardness of our country with regard to utilisation of energy compared to other countries. The figures given below would show the comparative positions.

Country	*Per capita consumption of electricity* (1956)
U.K.	1862
U. S. A.	4095
OEEC	1346
India:	21 (1956)
	50 (1960-61)

Assuming that India would attain the standard of living at present (1956) enjoyed by the developed countries like the U.K. or the U.S.A. after some fifteen years let us estimate the capacity that would be necessary to bring this country to that stage. From the table it will be seen that present consumptions per capita in the U. S. A. and the U.K. are 4095 and 1862 respectively. This means that the standards enjoyed by these countries are 80 times and 40 times more than the standard maintained in India.

While in Europe, America and U. S. S. R. during the next eight or ten years more and more of the demand will be met from the nuclear power stations, we do not expect more than 4 to 5 million kilowatts of nuclear power by then. From 1970 onwards scientific development on nuclear power is bound to reach a stage when all major power developments throughout the world will have to be met by nuclear plants only. It could, therefore, be reasonably expected that a target of 56 million kilowatts by 1975-76 may not be considered very optimistic to achieve.

The consumption per capita in the U. K. and the U. S. A. by 1975/76 will reach figures of 3000 and 6000 respectively, taking the mean rate of development in those countries. It could, therefore, be seen that even if we reach a consumption figure of 400 units per capita how much we shall be laggign behind.

New Trends in the Design of Axial Flow Units

By PIERRE L. MISSON and INDRU T. ADVANI
Engineer Director and Project Engineer, Establissment Neyrpic

It is evident that with a given discharge of water the output that can be obtained is greater if the head is correspondingly higher.

It is on account of this that the hydro-electric engineers have always paid greater attention to the harnessing of high head and medium head plants calling for the use of impulse and Francis turbines. However, the number of large well defined plants operating under high and medium heads is well nigh limited particularly in Europe and the hydro-electric engineers are being steadily pushed to look for the harnessing of lower and lower heads.

In spite of great improvements made in the design of conventional low head turbines, there is a limiting value of the head under which generation is not considered to be economical. It has more or less been felt that the cost per kilowatt of installed capacity is prohibitive for heads lower than 15 metres (50 ft. approximately). This arises mainly due to the fact that the turbines of a reasonable output operating under such heads are very big in size and so also are their low speed generators. Moreover, from the civil engineering view point it is found that the conventional vertical shaft turbine entrains large excavations if due care has to be taking to protect the turbine runner from phenomenon of cavitation.

In face of a limited potential of hydro-electric energy from high and medium head plants, the hydro-electric engineers have been forced to think furiously about finding alternate designs which would permit bringing the harnessing of low heads within the limits of economic operation.

After years of patient and continued research some turbine manufacturers have come to the conclusion that low head generation shall be economic only if a massive reduction in costs is obtained in the civil engineering work and it was felt that this could be achieved only in an arrangement where the axis of the generating unit is in the same direction as the axis of the turbine flow.

Hydro-electric engineers have paid attention to this problem ever since the early twenties. In 1923, Abbe Cayere, the Chief Engineer of Etablissements NEYRPIC proposed an arrangement whereby he envisaged a bent tube with the turbine lodged at its interior. The turbine shaft emerged from the bend and it was coupled to a conventional generator, and a gland packing was provided at the region where the shaft emerged from the tube. In between 1919 to 1924 the U. S. consulting engineer Mr. Harza registered several patents for an original arrangement with a horizontal shaft propeller turbine having the poles of the generator mounted at the periphery of the blades. This dea was taken up a later date by M. Arno Fischer and several units of this type have been installed in Germany.

The French have been devoting considerable thought to the development of low heads, since due to the demand of electric energy going up in the geometric progression in France, the French engineers have had to work furiously upon the harnessing of tides. In fact it has been possible to design units for the Rance tidal schemes, which have an extremely versatile operation.

Basic Design Features

As mentioned in the introductory paragraph, a continued research has been undertaken to slash the cost of the plant machinery and the civil engineering works.

In order to achieve this end the following basic features have been incorporated for this new type of low head machines:

— The generating unit is either horizontal or slightly inclined,

— The draft tube is rectilinear as far as possible instead of the bent draft tube used for conventional turbines. An exception exists however for the siphon type of bulb units which shall be explained later.

— The runner is of th propeller type, having either movable or fixed blades,

—The generator is totally of the new type as shall be explained in the succeeding pages.

At the very outset of this development the turbine manufacturers, before proceeding to the manufacture of large sized units introduced the manufacture of small low output units for experimental purposes. However, it has been noticed that such small units hold a considerable interest for the generation of energy.

In order to reduce the size of the generating unit, the generator had to be extremely compact in design. The question of the dissipation of friction losses arising out of the rotation of the generator in the working medium had to be suitably dealt with and it is in fact this question that has led to the fixing of the following criterion.

—It was decided that for outputs less than 4000 kW approximately the generator shall be of the induction type rotating in oil. The rotation of the generator in oil leads to friction losses which would be higher as compared to the unit rotating in air by 1% of the output of the unit. The dissipation of this energy offers no serious problems since the coefficient of thermic conduction of oil is approximately 10 times greater than that of air and the coefficient of convection of oil is several times greater than that of air even for small velocities of oil circulation, and furthermore oil transfers the heat to the water flowing past the generating unit. The utilization of oil as the working medium also presents the advantage that it offers convenient lubrication of the bearings and insulation of the stator windings.

For outputs higher than 4000 kW it was decided to provide for synchronous generators rotating in air. This has been done for two reasons. Firstly, with large sized machines the friction losses with the generator rotating in oil are considerable and secondly, due to the fact that for synchronous machines, slip rings and carbon brushes are necessary whose operation becomes very delicate if they are situated in oil.

A third type of unit has been developed whereby the generator of the conventional type is lodged in an upstream pier and a horizontal shaft Kaplan turbine is connected to it. This unit has its own domain of utilisation as shall be explained in the succeeding pages.

Bulb Units for Micro Power Stations rotating in Oil

As stated previously these units are provided with an induction generator rotating in oil. At the very outset it should be borne in mind that such plants cannot operate independently but they have to be connected to an existing net-work supplied synchronous machines which would fix the frequency of the bulb units and also supply the necessary reactive power. Moreover these units due to their extremely compact design do not possess the necessary flywheel effect to ensure the necessary frequency regulating.

The small bulb units have been designed with a view to harness the plethora of small head drops ranging between 5′ to 40′ which would certainly be beyond the scope of economic generation from the conventional plants. It has been attempted to design units which firstly require minimum capital cost for both the purchase of the plant machinery and the execution of civil engineering works; secondly these units have to possess an operation which should be automatic requiring the minimum of suprevision, and finally the units should be of extremely robust construction.

The generating unit consists of a turbine of the Kaplan type. The generator is lodged in an upstream bulb which is filled with oil The oil is maintained at a higher pressure as compared with the surrounding water by the provision of oil tanks (refer figure 1) situated at an elevation higher than the maximum head water level. This is very important as otherwise the slightest admission of the surrounding water into the oil shall tend to produce a short circuit of the generator coils.

These units can have either movable blades (if large variation of head is to be reckoned with) or fixed blades. The movable bladed runner, however, leads to a substantially costlier turbine, the fixed bladed unit being much more simple in construction and operation.

These units possess the maximum of simplicity. The rotor body is fixed by means of 5 bolts to the stay ring of the turbine. After the embeded parts have been firmly grouted it is possible to erect the monoblock bulb unit consisting of the turbine od the generator within a period of 48 hours.

These units can possess the following alternate layouts:

(*a*) Axial layout
(b) Siphon layout.

(*a*) *Axial layout*

Figure 1 representing the section of the power house of the Castet power station in France, shows a typical axial layout provided with upstream gate control. In certain cases the control gate is provided at the downstream side with only stop logs at the upstream end. The Castet Units have been operating since a long time and they are giving entire satisfaction.

These units are utilised for heads ranging between 2.5 meters to 11 meters.

The table below gives the list of axial layout units manufactured already:

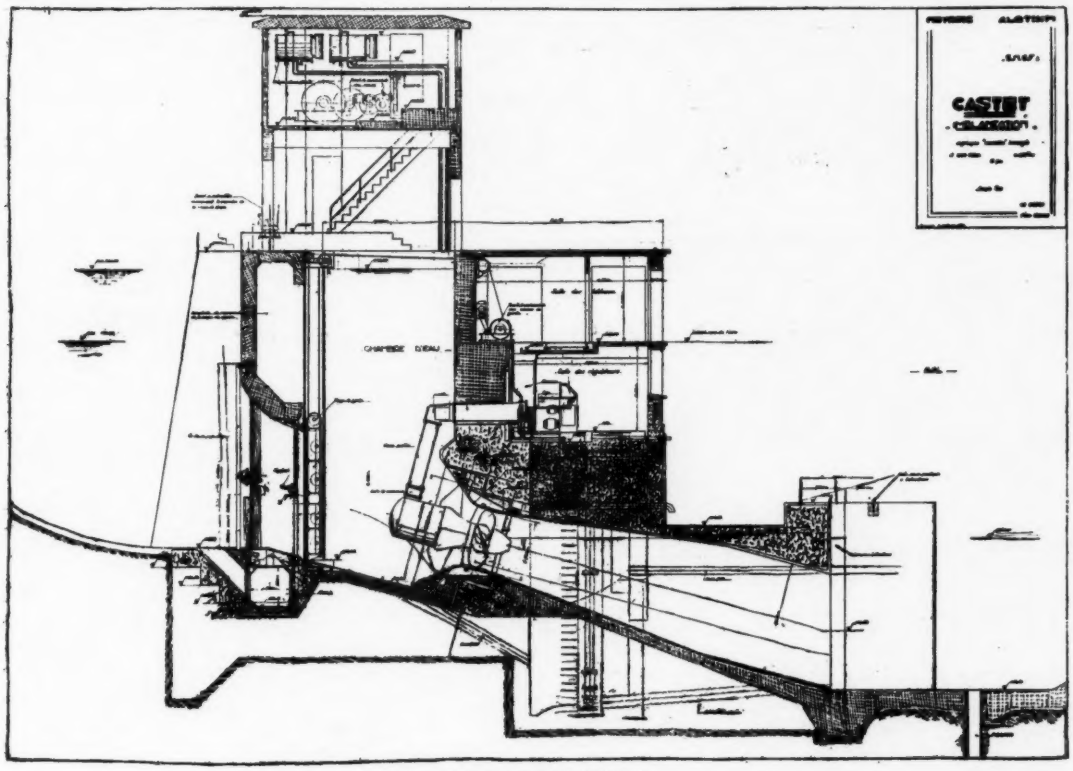


Fig 1.—Axial Layout Bulb Unit.

A. Moveable Blade Units

Name of Installation	*Year*	*Head in Meters*	*Output H.P.*	*Rotational Speed R. P. M*	*Diameter of Runner mm.*
Castet	1951	7.5	1000/1100	250	1650
Mercues I	1952	3.5	325	187	1650
Verdun	1955	3.13	327	187	1650
Rethel	1955	2.50	250	176.5	1650
Esch sur sur	1958	3.0	425	176.5	1800

B. Fixed Blade Units

Name of Installation	*Year*	*Head in Meters*	*Output H.P.*	*Rotational Speed R.P.M.*	*Diameter of Runner mm.*
L'ame	1953	1.90	194	165	1600
Lagarde	1955	2.25	250	182	1600
Capdenac	1956	6.00	1100	250	1800
Mercues II	1956	3.90	432	254	1400

(*b*) *Siphon layout*

Figure 2 shows the siphon layout. It will be seen that this arrangement is simplicity personified. The civil engineering works consist of a small concrete weir above which the siphons are istalled. During the initial stages of development the siphon upstream of the bulb was made of steel plate, but now an improvement has been brought whereby this portion is made out of concrete. The starting and stopping operations of the siphon are very simple. The crest of the siphon is placed just above the normal head water level and the lower portion of the draft tube is always drowned. A battery of siphons is provided with a single motor driven vacuum pump and each siphon is provided with its individual float mechanism. In case the head water rises over a predetermined value, the float system of any given siphon operates the vacuum pump which produces vacuum in the corresponding siphon due to the siphon being sealed and the turbine starts operating. The motor of the vacuum pump ceases to operate when the water level inside the siphon reaches a certain value.

In order to stop the turbine, air is admitted into the siphon and the unit is automatically brought to rest. This type of unit is usually utilised for head until 3.5 meters.

The table hereunder gives the list of the installations of this type:

Siphon layout Units

Installation	*Year*	*Head in Meters*	*Output H.P.*	*Rotational Speed R.P.M.*	*Diameter Runner mm.*
La Maignannerie	1952	1.85	89	224	1120
La Caillade	1955	3.50	209	250	1120
Marcillac	1957	3.0	165	257	1120

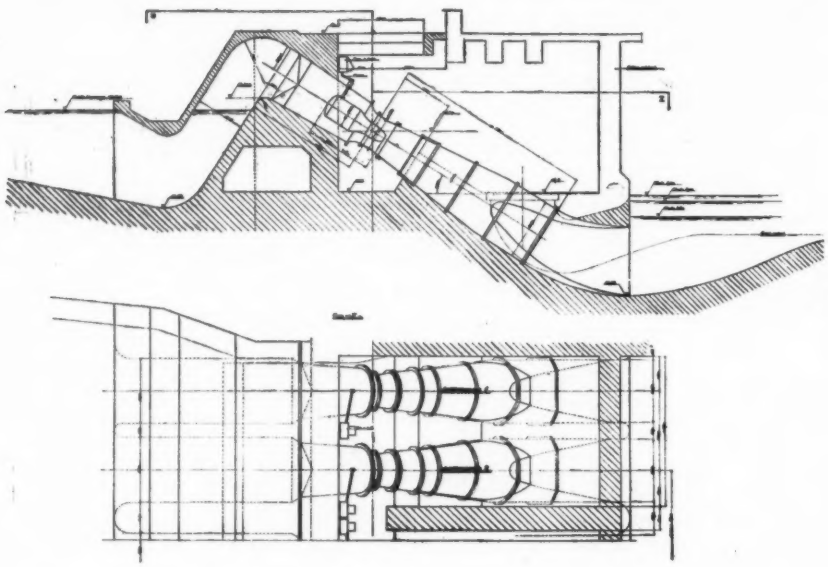


Fig. 2—Syphon Layout Bulb Unit.

It has been felt that in order to obtain drastic economy an attempt should be made at standardisation of bulb units. Hydraulic turbines have always been considered to be tailor-made machinery, and it has always been the irrealisable dream of the hydro-electric engineers to standardise their manufacture. This dream has manifestly been achieved for the small sized bulb generating unit. Such standardisation can eventually help to slash costs and delivery time.

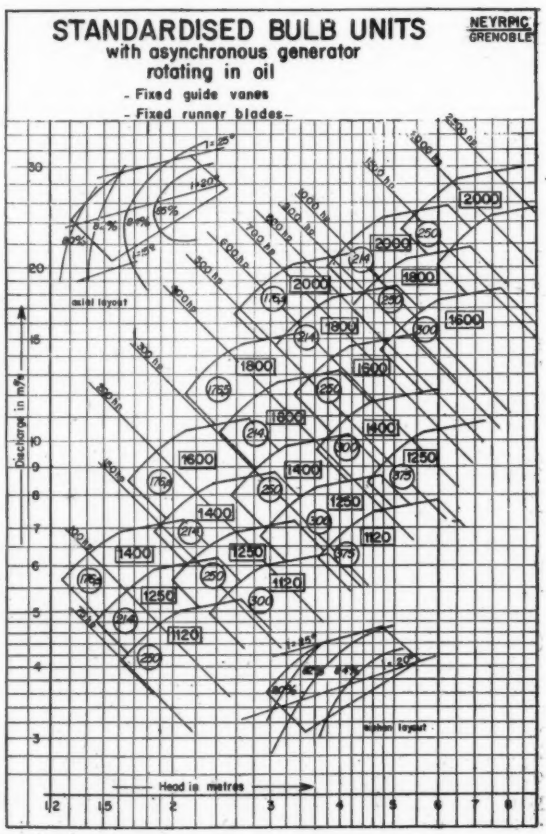
Figure 3 represents the provisional chart representing the standardisation of fixed bladed bulb units. On the abcissa is represented the head in meters and on the ordinates the discharge in cubic meters per second. The curvilinear polygons represent the domain of utilisation of a bulb of a given diameter and rotational speed. The dark figures inside the polygons indicate the diameter of the standardised runner and the figures in circles the rotational speed. By transposing the curvilinear polygons, the approximate figures of the expected efficiencies can be obtained. It can thus be seen that the maximum efficiency of 85% can be anticipated with an axial layout and that of 84% for a siphon layout.

Figure 4 shows the provisional chart representing the standardisation of moveable blade type bulb units. The maximum efficiency amounting to 90% can quite conveniently be anticipated and in fact the Castet turbines on industrial measurements have given efficiencies exceeding 90%.

The bulb type of generating units permit a very substantial slashing of costs for the following reasons:

—The axial arrangement permits a very large saving of costs of excavations due to the presence of a rectilinear draft tube in place of the bent draft tube for conventional unit.

Fig. 3.



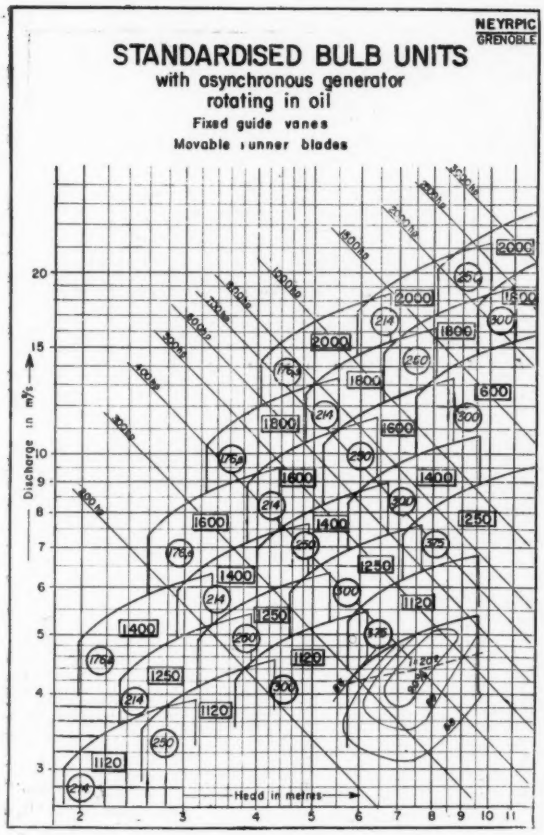


Fig. 4.

—Due to their compactness,these units permit a substantial reduction in the distance between the axes of thesuccessive units, thus giving the corresponding reduction in length of the power house.

—The complicated civil engineering works involved for installing a spiral casing are altogether eliminated and in case of the open chamber type of arrangement evn a contractor of moderate experience can conveniently undertake the civil engineering work.

—Above all, the erection timeis reduced many fold as compared with a conventional Kalpan turbine. It has earlier been stated that after embedding the fixed parts it is possible to erect the turbine and generator unit within a period as short as 48 hours.

In fact the very limits of simplification have been reached for the siphon layout. Only a small concrete weir is required to install the units and not even gates or stop logs are necessary for performing the erection or dismantling of the unit.

According to a study carried out by the Eectricite de France the economy in the Civil engineering works ranges between 10% to 60% depending upon the type and characteristics of the installation.

As far as the generating machinery is concerned there is a reduction of weight of 50% as compared with a conventional unit of the same output.

Axial Flow Bulb Units with Synchronous Generator rotating in Air

We shall proceed now to examine another type of unit which is quite different from the bulbs for micro-power stations that we have just discussed. In fact these units, by virtue of their large output and size are required to give a performance very similar to that of the conventional machines and the question of the efficiency of the unit plays an important role in their design, in contrast to the small bulb units.

These units comprise essentially the following items:

(*a*) A set of stay vanes

(*b*) A set of movable vanes

(*c*) A conventional Kaplan runner with the exception that the distributor upstream of the blades is conical.

(*d*) A generator is lodged in a bulb either upstream or downstream of the turbine runner.

Figure 5 shows the general arrangement drawing of a bulb unit with the runner diameter of 3.800 meters having the bulb placed upstream of the runner. These units possess the obvious advantage that the civil engineering works are considerably reduced due to the fact that firstly the distance between the centre lines of unit is considerably reduced and secondly the excavations are positively diminished due to the absence of a bent draft tube which exists for the conventional machines.

The bulb unit can be adapted to possess an extremely versatile operation. By bringing about a certain number of modifications in the hydraulic profile of the turbine and also the operating mechanism it is perfectly possible to design a unit capable of working as turbine-cum-pump and that also with two alternate directions of flow. It is thanks to this versatile operation rendered possible by these units, that it is now feasible to harness the energy of the tides.

At the initial stages of this devlopment, these units were provided with the bulb incorporating the generator downstream of the runner but now-a-days the solution with the upstream bulb as shown in figure 5 is being increasingly retained.

The table hereunder gives the characteristics of the large sized bulb unit already manufactured:

A. Generator bulb downstream of runner

Installation	*Year*	*Head in Meters*	*Output in H.P.*	*Rotational speed R.P.M.*	*Diameter of Runner mm.*
Argentat	1953	16.5	19,250	150	3800
Cambeyrac	1953	10.75	7,000	150	3100

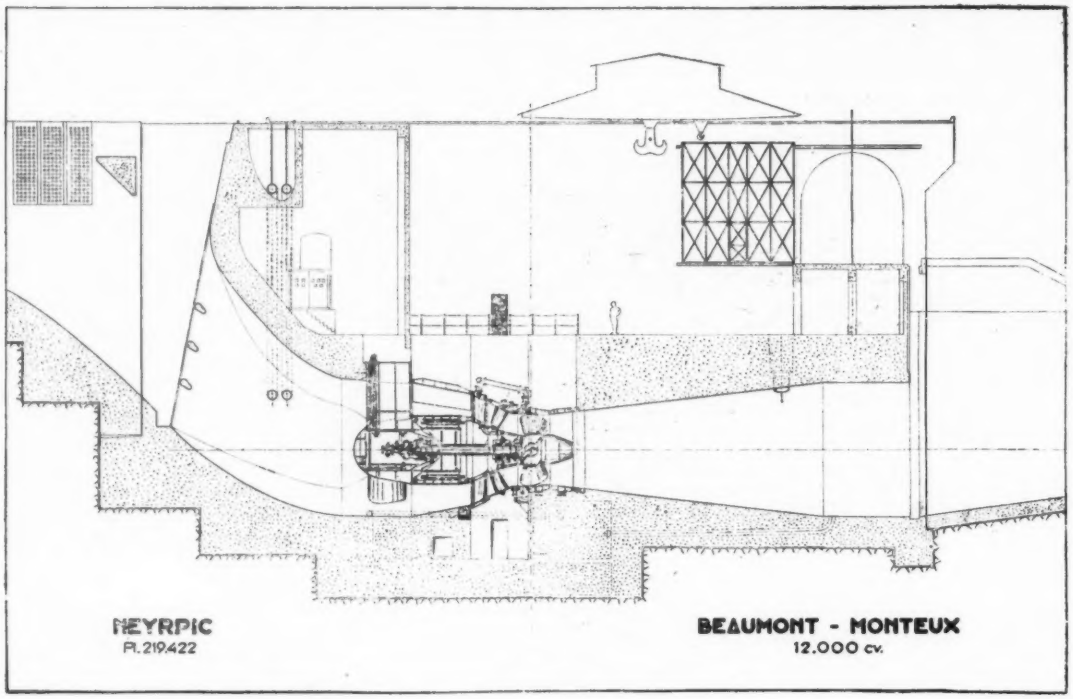


Fig. 5—General Arrangement of Bulb Unit rotating in air

This two units are already operating and they have proved to be a total success.

B. Generator bulb upstream of runner

Installation	*Year*	*Head in Meters*	*Output in H. P.*	*Rotational speed R.P.M.*	*Diameter of Runner mm.*
Beaumont-Monteux	1955	11.3	12,000	150	3800
Saint Malo	1956	5.5	12,000	88	5800

The large sized bulb units cannot the transported monoblock as is the case for the units dealt with in the preceding chapter, and the complete erection has to be performed at site like that of a conventional machine which warrants the provision of a dismantling day. The unit has to possess a certain minimum size in order to permit access for inspection and repairs of the parts lodged at the interior of the bulb.

Pier Type of Units

We now pass on to another type of axial flow design which is perhaps the nearest to the conventional designs.

Figure (6) represents the general arrangement of projected installation comprising 3 units of this type. It can be seen that this installation comprises horizontal shaft Kaplan turbines placed inside tubes (the guide vanes are fixed but the runner blades are movable). A conventional type of generator is placed in an upstream pier which protects the generator against all contact with water. In order to reduce the size of the pier and the generator the generator speed is stepped up by means of a speed multiplier. This arrangement gives not only a compact arrangement but it also reduces the generator cost very substantially.

The bulb units explained in the two preceding chapters cannot operate in isolated networks since they possess the basic lacuna that by virtue of their compactness the flywheel effect of the generator is so small that they cannot do any frequency regulation.

However, this type of unit can overcome this drawback since firstly, the generator is of the conventional type, secondly, a flywheel can quite conveniently be introduced (as can be seen in figure 5) which can supplement the total flywheel effect and thus permit the operation of such units in an isolated network.

These units are more economical as compared to the conventional plants though the reduction in costs is not as drastic as that anticipated from the bulbs for micro power stations. M. Boussuges, Chief Projects Engineer of Etablissements Neyrpic in his paper before the Societe Hydro technique de France states that the reduction in costs for the plant machinery consisting of turbines, generators, lifting gantry, trash sacks, gates, stop logs, handling charges and erection cost is of the order of 30% as compared to a conventional plant.

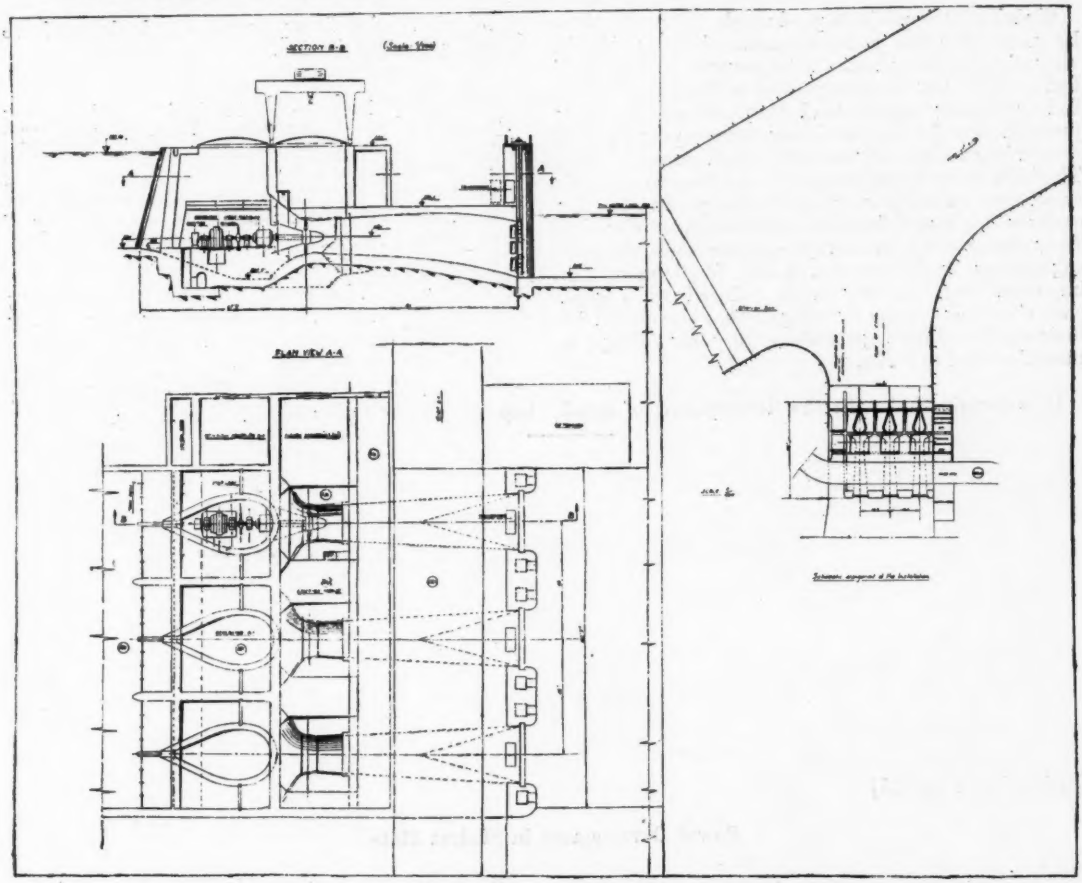


Fig. 6—Pier type of units

An installation having 4 units of this type is already in operation and it has following characteristics:

Installation	*Year*	*Head in Meters*	*Output in H.P.*	*Turbine Speed R.P.M.*	*Generator Speed R.P.M.*	*Diameter Runner mm.*
Wadrinau	1954	4.6	2,020	10F2/3	600	3050

Role of new Axial Flow Units in Indian Planning

The development of low head generating units has brought in its wake new designs and altogether new conceptions in the field of hydro-electric engineering.

First and foremost, with the new type of micro power stations, the notion of a new 'type' of electric energy has come forth, this energy having the advantage that it involves little capital investment from sites readily available and it can be obtained in a comparativelyshort space of time. On the other hand this energy is not of a nature that it can feed into an isolated network, but it has to be super-imposed upon an existingnetwork which would supply the reactive kVA and which would also maintain the frequency of operation.

Such units can be installed in numerous places in India. The head drops existing in the canal networks in North India (where there exist large discharges) can be easily harnessed by the induction type bulb units. In this case the siphon arrangement may prove to be particularly invaluable since it can be placed coveniently for heads upto 12-14 feet. The electric energy produced could be connected to the electric grid fed by large power stations. This additional energy having low cost per killowatt of installed capacity could be utilised to operate the drain pumps for alievating the problem of water logging.

Similarly in south and east India there exist several drops which can very conveniently be harnessed. A rough computation of the investiment required for such stations has shown that the cost ranges anywhere between Rs. 600 to Rs. 1,500 per killowatt of installed capacity, depending upon the type of the unit and its civil engineering works. This cost is very much lower as compared to the conventional power plants.

Hydro-electric projects produce electric power 8 to 10 years after the commencement of the works. In view of the pressing demands for power in all regions of India, there has come to prevail a notion amongst India planning experts (and this notion is perfectly justified) that for the time being thermal power plants should be given priority since they yield quicker results. The bulb units for micro power stations reverse this trend since micro power projects can produce energy easily within 2 years from the commencement of works. They create less human displacements since the civil engineering works are small and furthermore the imported items are very much reduced as a good part of the low tension switch-gear that is required for their use (these units generate at very low voltage) is manufactured in India.

It is certain that with the development of zonal grids in India, the micro power station bulbs can have a much greater utilisation.

However, the problem of supplying energy to isolated pockets is by no means resolved and the 'pier' type of units come to fill in this lacuna. Such units can operate without receiving assistance from an existing network. However, these units must have a minimum size and they cannot be classified in the category of micro power stations.

The large sized bulbs can also have an interesting utilization in India and as in Europe they can gradually replace the Kaplan units for heads until 25 meters.

It is undoubted that these developments have an important role to play in Indian Planning.

Continued from page 85]

Power Development in Madras State

Bombay and Bengal leading. In the matter of hydro electric development Madras is second only to Bombay.

Future Plans

Demand for power in the State is widespread and insistent. Several new industries are being planned all over the State and power for them is to be provided from the grid. The important industries coming up in the State are the aluminium industry, soda ash plant, raw film factory, paper factory and additional cement factories. The requirements for these are estimated at 120,000 kW. Apart from these the department will have to meet the growing requirements of small scale industries and the lignite mining road apart from demand from rural areas.

To meet the growing demand which is expected to be of the order of 549,000 kW in 1961-62, new power sources have to be tapped. Sanction of the Government of India is awaited for the Mettur Tunnel Scheme to utilise the irrigation discharge at Mettur Dam which will give 200,000 kW seasonal power for seven months. The investigations of the Palar—Porandalar and Kumbar—Amaravathi Scheme have just been completed while the investigations of Kundah ultimate phase is under progress.

The integrated Neyveli Lignite Scheme of the Government of India contemplates the erection of a thermal station of 250,000 kW capacity and it is expected that about 200,000 kW of power would be made available to the Madras Grid.

The recent conclusion of an agreement between the Kerala and Madras States regarding the Parambikulam Scheme has opened up further possibilities in the power development of the State. It is estimated that about 150,000 kW of additional power will be available to Madras from this scheme.

Nuclear Generation

With the exhaustion of the development of the potential water sources from which power can be developed economically, the Board may have to resort to nuclear generation.

The Union Minister for Home Affairs, during the Southern Zonal Council meeting at Trivandrum recently indicated that the Government of India were considering the proposal for establishment of a nuclear power station in Madras State. It is hoped that this nuclear station will materialise before the end of the Third Plan period to meet the ever-increasing demand for power.

Power Development in Madras State

By V. P. APPADURAI,
Chief Electrical Engineer
Government of Madras

The Madras State has no oil deposits. Until recently it was believed that it had no coal deposits either. Only a few years back lignite or brown coal was located near Neyveli in the South Arcot District about 120 miles south of Madras city. The power development during the earlier years was therefore confined to development of hydro potential of the State.

Power generation in the Madras State until about 1908 was confined mainly to a few tiny plants in tea estates run on water power, and to the small hydro installation at Kateri in the Nilgiris.

The first public electric supply in the State was commenced in Madras City in 1909 by the Madras Electric Supply Corporation under licence for the establishment of a thermal station.

Real progress dates from 1925 when the Government of Madras initiated the policy of active development of the hydro electric power resources by the State.

In furthernce of this policy, the first hydro electric scheme viz., the Pykara Scheme was taken up in 1929 and the station commissioned in 1932. The Mettur station came into operation in June 1937 and the Papanasam Power House in April 1944. The first thermal station to be erected by the department was commissioned early in 1951 at Madurai.

During the First Five Year Plan a new power house at Moyar was commissioned and extensions to the existing stations at Pykara, Papanasam, Madurai and Madras were added.

This year 1958, has been very significant in the electrical development of the State with the soinning of the biggest hydro set at Periyar and the biggest thermal set at Madras. The installed generating capacity has increased during this year by 25 per cent from 256,500 kW to 321,500 kW.

Planning

Planning in Madras State has always been on the basis of ten year schemes so that the schemes when completed will meet the immediate loads as also the loads coming in the near future. This has been found satisfactory as the ten year period is adequate for investigation, planning and execution of new hydro electric projects.

In planning, it has been the objective of the department to cover the whole State with an extensive grid. This grid was planned so that eventually it would link the several hydro electric and thermal stations in the country and convey their power to the consumers in all villages and towns through a net work of transmission and distribution lines.

The grid at present covers all the districts of the State except the Kanyakumari district which has recently been formed after the reorganisation of the States. This district at present is getting power supply from the Kerala State and will be fed from the Madras Grid shortly.

The grid comprises five hydro electric power houses:

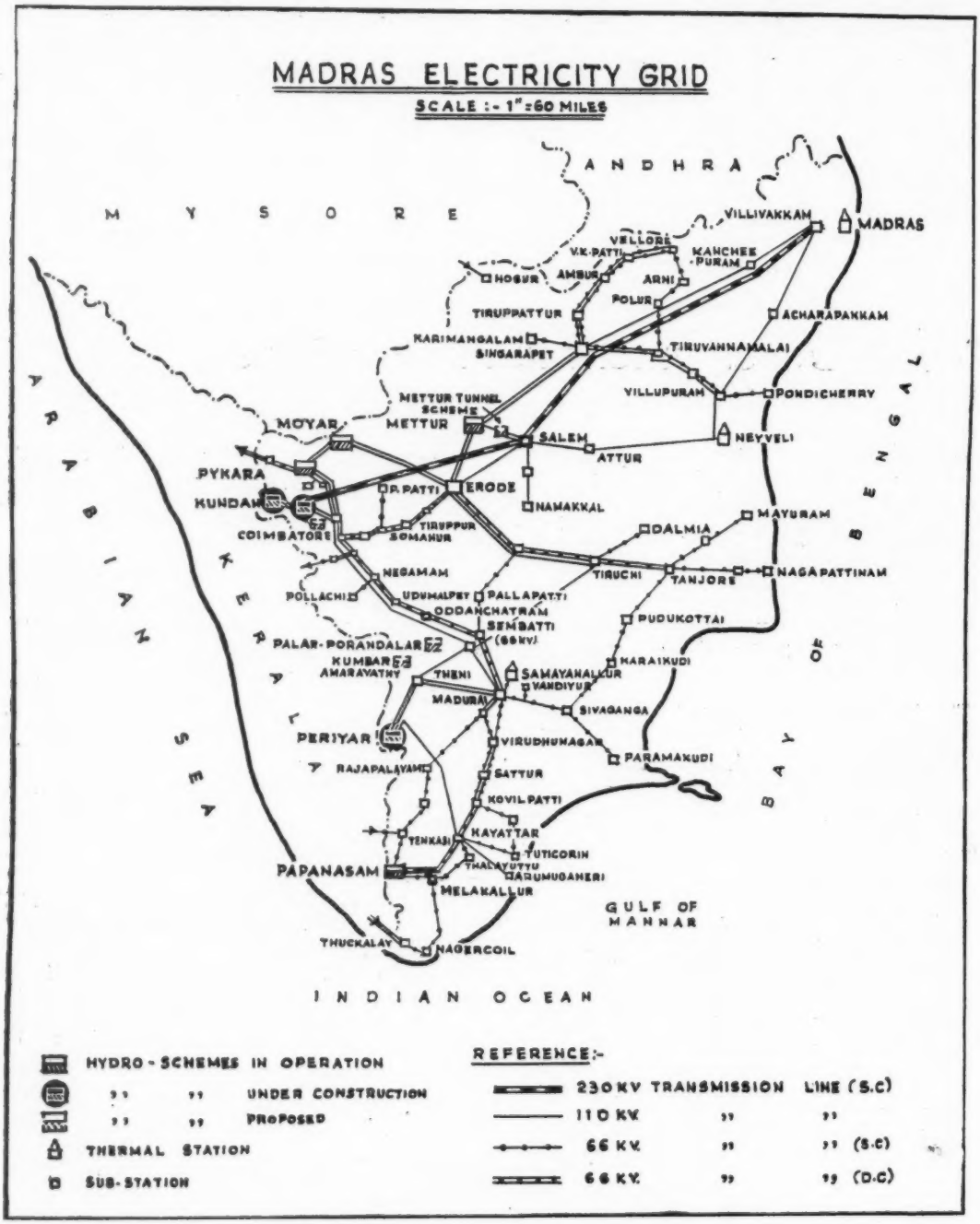
	Installed capacity
Pykara ..	70,000 kW
Moyar ..	36,000 kW
Mettur ..	40,000 kW
Papanasam ..	28,000 kW
Periyar (1st Unit) ..	35,000 kW

two thermal power houses:

Madras ..	98,500 kW
Madurai ..	14,000 kW
	3,21,500 kW

11,300 miles of high tension transmission lines of voltages varying from 11,000 to 1,10,000 ;

15,250 miles of low tension distribution lines;



and 56 E. H. T. and 61 H. T. substations and 7,040 distribution stations.

Second Plan

The power schemes of the Madras State included in the Second Five Year Plan envisage more than doubling the installed capacity, length of lines and the number of towns and villages electrified. The Table I gives the targets for the Second Plan under generation, transmission and distribution for the Madras State; for purposes of comparision the All India targets are also given.

Progress

Generation

The Madras Plant Extensions (III stage) which

Table I

Particulars	*All India target*		*Percentage increase*	*Madras*		*Percentage increase*
	1955-56	1960-61		1955-56	1960-61	
Generation:—						
Installed generating capacity in 1000 k.W	3400	6800	100	256	571	123
Units generated in millions	11000	22000	100	1055	2100	100
Transmission:—						
H. T. lines—11 Kv. and above.	35000	70000	100	7343	15500	112
No. of villages and towns electrified	7400	18000	145	3543	8500	156
Per capita consumption in units.	25	50	100	25	60	140

envisaged the erection of a 30,000 kW set with two numbers 150,000 lbs./hr. boilers were commissioned in April 1958.

The first unit of Periyar Hydro Electric Scheme was commissioned in October this year and the second and third units are expected to be commissioned early in 1959 adding 105,000 kW installed generating capacity to the grid.

For the Kundah Hydro Electric Scheme, civil works are in full swing in all the dam sites, tunnels and the power-house sites. The generators for the first plant have already been shipped and it is programmed to commission the first unit by June 1959. The initial phase comprising of the first two stages will be completed within the plan period and will add 180,000 kW installed generating capacity to the grid.

Transmission

Including the transmission lines proposed under the Kundah and Periyar Hydro Electric Schemes, an additional 8,200 miles of E. H. T. and H. T. lines and 8,000 miles of L. T. lines will be erected during the Plan period. Of these, 3122 miles of E. H. T. and H. T. lines and 5739 miles of L. T. lines have already been erected during the first two years of the Plan period. A major stride in respect of transmission during the Second Plan period will be the erection of the first 230 line in the State from Kundah to Madras which will convey power generated at Kundah to Madras, a distance of about 300 miles.

Rural Electrification

Madras continues to maintain its lead in the matter of rural electrification with over 7300 towns, villages and hamlets electrified by 1958. During the Second Plan period, it is proposed to extend electricity to 5,000 additional villages. Of these about 2620 have already been electrified during the first two years and 900 villages in the first nine months of the current year. About 32,440 pump sets were working on electricity at the end of the First Plan period. Today nearly 75,000 pump sets are deriving the benefits of electricity.

The Table 2 gives the power development of the Madras Grid under Five Year Plans. It may be seen from the table that there has been a phenomenal development during the last four years.

With the commissioning of the 30,000 kW set at Madras and the 35,000 kW set at Periyar Madras ranks third in generation and utilization of power

Table II

Electricity Development under the Five Year Plans.

Sl. No.	*PARTICULARS*	1950-51 *Before the First Plan*	1951-52	*FIRST FIVE YEAR PLAN.* 1952-53	1953-54	1954-55	1955-56	*SECOND PLAN.* 1956-57	1957-58
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
I.	*Generation.*								
	Installed Generating Capacity in MW.	157.4	163.80	200.33	225.6	256.7	256.7	256.7	286.7
	Aggregate demand in MW.	130.8	146.00	143.60	151.9	181.6	208.6	233.85	252.35
	Units generated in Millions.	630.97	730.85	701.66	758-7	933.6	1053.28	1135.20	1344.92
II.	*Transmission.*								
	Length of E. H. T. & H. T. lines in miles.	4355	4829	5022	5420	6101	7343	9065	10,465
	Length of L. T. lines in miles.	3580	4498	4926	5140	5932	8128	11006	13,867
III.	*Rural Electrification.*								
	Number of villages electrified.	1613	1820	1981	2089	2392	3321	5016	6,373 (268 Towns)
	Number of pumpsets connected.	14373	15904	18481	21733	24654	32440	45173	62,561

Continued on page 82]

Power Development in Madhya Pradesh

By M. K. R. MENON
Superintending Engineer (Projects)
Madhya Pradesh Electricity Board

The new State of Madhya Pradesh comprising the Mahakoshal Districts of the erstwhile M. P. State, the Madhya Bharat, the Vindhya Pradesh and the Bhopal regions has an area of 171900 square miles and a population of 26.07 millions. The State has large potential in natural resources. It has rich tracts of agricultural land, extensive forests yielding good quality timber, and abundant mineral deposits such as coal, iron ore, manganese ore, bauxite, lime stone and other. The distribution of minerals is shown in Table I. For power development, the State has a hydro-electric potential of 4 million kilowatts.

Inspite of such large potential, the various parts of the State have remained comparatively backward. The State has a high percentage of tribal people particularly in the Eastern regions and about 80% of the population is still dependent upon agriculture.

History of Growth of Electricity Development

Prior to the commencement of the first Five Year Plan except in the Mahakoshal and Indore regions, there was but little co-ordinated long-term planning for development of electricity in the State. The power supply was mainly confined to urban areas with isolated small generating stations run by diesel engines and a few bigger ones with steam power. The major power supply undertakings were mostly managed by private agencies. The Government owned electric undertaking in the erstwhile princely States were mainly intended for serving the needs of the palace and a few leading elite of the capital towns.

With the attainment of independence and the objective set for large-scale planning and economic development, electric power development accepted as the "Key Stone" of the main arch of progress, assumed high priority. A few schemes had in fact already been initiated in some of the areas for sizeable developments even before the commencement of the first Five Year Plan. Most of the schemes however excepting a few notably in the Maha koshal region, were still on a short-term and conservative basis. This was largely due to lack of financial resources for implementation of the schemes and absence of a clear picture of the likely demand of the area.

Pattern of Power Development during the First Five Year Plan

The power development envisaged during the Plan was essentially one for catering for the immediate requirements of the area where the existing supply position was unsatisfactory and pressing demand for industrial and other purposes from the public was coming up. Apart from replacement power, the requirement of the surrounding areas where specific proposals had been initiated for industrialisation was also taken into consideration in addition to the schemes to electrify as many towns as possible with a population of 10,000 and above.

Having regard to the limited objective, there was but little choice in deciding upon the source of generation. For small and medium sized isolated plants upto 500 kW capacity diesel power was considered as the most economic source of generation as diesel stations could be installed expeditiously. For bigger sized plants thermal generation by coal was adopted in view of the vicinity of coal fields in the Pench valley and V. P. regions. The necessity for speedy completion of the projects due to power shortage in the area and limited capital outlay were the additional guiding factors in deciding upon thermal generation with coal. Further, in spite of large hydro-electric potential in the State it was not possible to consider hydro-electric generation owing to lack of various preliminary data and the time required for investigation, planning and execution of such schemes. The only major scheme taken up for investigation was the Chambal Hydro-Electric Scheme on the border of the erstwhile Madhya Bharat and Rajasthan region.

Preliminary investigations of a few minor schemes were also conducted either by the State P. W. D.

organisation or the Central Water and Power Commission. But none of these schemes had reached any final stage for execution during the First Five Year Plan.

With the enactment of the Indian Electricity (Supply) Act (1948) it became an accepted policy of the State Government to own and operate all electrical undertakings of the future and to take over wherever possible all private undertakings subject to the usual conditions of agreement. In this context the notable features of the development of electricity in the State during the First Five Year Plan are: (*a*) the initial development was essentially by coal fired steam stations and to a limited extent with Diesel Generation and (*b*) the expansion of electric generation in the public sector overstepping that in the private sector.

Works Completed and under Execution during the First Five Year Plan

As the integration of the constituent units in the new M. P. under the States Reorganisation Act took place only during the Second Five Year Plan, the works executed during the First Plan period are given regionwise. After the integration of various constituent units and the assumption of responsibility by the M. P. Electricity Board for electricity development over the entire State, an integrated development plan for the entire region divided into various power systems transcending geographical boundaries became possible. This will be discussed in the sequal. The various works that were completed or were under execution by the end of the First Five Year Plan in the various constituent units of the State are mentioned below.

(*a*) *Mahakoshal Region of The M. P. State*

(*i*) The Pench valley coal fields and some of the important towns and villages (22 nos. in the Chindwara and Balaghat Districts) were electrified from power made available from the Khaperkheda Thermal Station (3×10000 kW) in the Nagpur District of the M. P. State now transferred to the Bombay State over a network of 66, 33 and 11 kV transmission and sub-transmission lines.

(*ii*) A steam station with 2×2000 kW capacity was commissioned at Raipur to meet the growing demand of the Raipur town with extensions to other important towns of the Raipur, Durg and Bilaspur Districts over a 33 kV and 11 kV transmission system. 21 towns and villages were electrified from this station.

(*iii*) The Chandni Thermal Station with 17000 kW capacity was installed primerilly to meet the demand for power and steam of the National News Print and Paper Mills. Supply to Khandwa and Burhanpur areas was also extended from this power station.

(*iv*) A steam power station with 2×1500 kW capacity generating units was in an advanced stage of completion at Itarsi for supply of power to Itarsi and important towns and villages in Hoshangabad District.

(*v*) A double circuit 66 kV transmission line with one circuit only strung was completed between Jabalpur and Katni for supply to the licencee at Katni and to cope with the demand of Ordinance Factory. 17 towns and villages were electrified with bulk power purchased from the licensee at Jabalpur.

(*vi*) Five isolated diesel stations with an installed capacity of 1290 kW were also completed during this period.

(*B*) *Madhya Bharat Region*

In view of the investigation of the Chambal Hydro Electric Scheme by the Union Govt., no major generating stations were built excepting those which were essentially required to cope with the immediate requirements of the area already supplied with power as well as those essential to build up loads for utilisation of Chambal Power to be made available during the Second Five Year Plan.

(*i*) 3 Generating units with 13000 kW aggregate capacity were installed at the central power house, Indore.

(*ii*) One 2500 kW steam generating set was added at Gwalior Power House.

(*iii*) Nine diesel stations with an aggregate capacity of 2660 kW were added in the area.

(*C*) *Vindhya Pradesh Region*

In view of the future possibility of power supply from Rihand Dam project of the U.P. Govt. to this area, all the schemes, proposed were essentially of an interim nature with limited output to serve as nursary stations.

The augmentation of Satna Power House with small steam sets of 1810 kW capacity was initiated (but completed only during the Second Plan). 2 diesel stations with 250 kW installed capacity were also completed.

(*D*) *Bhopal Region.*

The only two power stations in this area were (1) Bhopal steam power house run by the State Govt. for supply to the Bhopal City and (*ii*) Sehore Diesel power house run by a licensee for local supply. A 2500 kW steam set was installed during the First Five Year Plan period at the Bhopal Power House and a second set of similar capacity was under erection.

Programme and Progress under the Second Five Year Plan

After reviewing the power postion at the end of First Five Year Plan it is now proposed to enumerate the plan for the next fifteen years. It may be mentioned that the new M.P. State had not been formed when the proposals for the Second Five Year Plan were formulated. Therefore the schemes proposed during the plan were regional and were not fully coordinated. After the formation of the new M.P. State, however attempts were made to draw up a master plan and fit in the proposed and continuing schemes

with the Master Plan. As a result, the area is divided into several power systems.

(*A*) *Korba Power System*

(*i*) *Korba Thermal Station Scheme*: Towards the end of the First Five Year Plan, the Union, Government had decided to locate one of the steel factories at Bhilai in the Durg District. The National Coal Development Corporation had also formulated a coal production scheme in the Korba and surrounding collieries. To meet the demands of these two key industries and of others in the Chattisgarh area, a 90,000 kW thermal station was proposed and taken up for execution at Korba in the Bilaspur District. The power supply to Bhilai Steel Factory will be transmitted over a 132 kV D.C. transmission line, feeding Bilaspur enroute. The mining areas at Dalli-Rajera and Deorjhal of the Bhilai Steel Project will also be fed from this system. The capacity is however quite inadequate to meet other demands in the area. This is clear from the recent load survey of the C.W.P.C., and acute power shortage even at the commencement of the Third Plan is apprehended. Proposals for extension by 150,000 kW (2 × 75000) have therefore been put up to the Planning Commisson. The proposed extension takes into consideration future extension of the Bhilai Steel Factory and increased production target planned by the National Coal Development Corporation. The scheme also provides for interconnection at Chirimiri of the Korba Power Station with the proposed 60,000 kW Amarkantak (Birsingpur) Power Station (mentioned later), the Rihand Hydro Electric Scheme and also with the Hirakud Hydro Electric Scheme at Raigarh through a 132 kV transmission system.

The system has also to cater for the future requirements of the Chindwara and Balaghat Districs which are now fed from the Khaperkheda Power Station of the Bombay State.

Considering that the complete planning and execution of a major thermal station takes about 3 to 3½ years, the extension could be completed during the year 1962-63 if the scheme were sanctioned immediately. Further developments on this system is discussed in connection with the Third and Fourth Five Year Plan periods.

(*ii*) *Extension to Raipur Station:* The installed capacity was increased by installation of an additional 4000 kW steam generating unit during the second plan period.

(*iii*) *Bhilai Diesel Station:* To supply the power demand of the Bhilai Steel Project during the construction stage, a 6000 kW (3 × 2000 kW) diesel station was completed during the early part of the Second Five Year Plan and to ensure optimum flexibility and economy in operation the station is working in parallel with the Raipur thermal station. Incidentally this is the biggest single diesel unit installed in India.

(*iv*) *Machkund Hydro Electric Project of Orissa Government*: Negotiations are already in progress for bulk power from this project for development of Bastar area where an iron ore project is contemplated in the Bailadilla area by the Union Government. Further, the Dandakaranya project proposed by the Union Government for rehabilitation of displaced persons comprises a large part of this area and its success will largely depend upon availability of cheap power for miscellaneous cottage industries to be set up under the scheme.

(*B*) *Amarkantak System*

The former state of Madhya Pradesh had planned to locate a 20000 kW thermal station at Katni for power supply in the Jabalpur-Katni-Sagar area. The Vindhya Pradesh Government had also planned two thermal stations each of 10000 kW capacity at Burhar and Satna to cope with the growing demands of the collieries and other industries of the area.

In view of the impending integration of the areas, the schemes were not proceeded with. On further consideration it was decided to install a 60000 kW station (2 × 30000 kW) in Amlai area. It will supply power to M. P. and V. P. regions where a number of collieries are already working and some more are to be set up by the National Coal Development Corporation. The station will also meet the power requirements of important industries such as cement and ordnance factories in the Katni area, the licensee's load at Jabalpur and Sagar as well as a large area in the V.P. and Mahakoshal regions of the State. With the increasing demand for power in this area, augmentation of power in the near future is inevitable and the State Electricity Board has already approached the Central Water & Power Commission to take up investigation of a few hydro electric schemes in the area. Details of these hydro-electric schemes are given later.

(*C*) *Satpura-Tawa-Bhopal Power System*

(*i*) *Itarsi Thermal Station* : 2 × 1500 kW generating units have been commissioned and 13 villages and towns electrified during the Second Five Year Plan.

(*ii*) *Bhopal Power Station* : A 2500 kW generating unit has been added and works are in progress for addition of a third unit. Besides, a double circuit 33 kV line has been completed for interconnection of Bhopal and Itarsi Power Stations to meet the increasing demand of Bhopal City where the capital of the New M. P. State and the Heavy Electrical Project of the Union Government have been located.

(*iii*) *Tawa Hydro Electric Project:* Investigation of the scheme which will yield about 11,000 kW has been completed and the works are proposed to be taken up in the Third Plan.

(*iv*) *Chambal Hydro Electric Scheme* : Power from Chambal Hydro Electric Scheme is expected to be made available to Bhopal by 1960-61 but in view of the increasing demand of the M.B. area it is very unlikely that any appreciable demand of this system could be met from Chambal for a long time.

(*D*) *Chambal Power System*

(*i*) *Indore—Gwalior area*: In view of the possible

availability of Chambal power during the later period of the Second Five Year Plan no major schemes have been projected. The laying of transmission and sub-transmission lines and installation of a few diesel sets to meet the requirements of existing diesel stations and to develop load in other areas will of course be necessary and provision will be made for them.

Power from Chambal scheme to the extent of 37500 kW by the year 1960-61 will be transmitted over 132 and 66 kV transmission system to bulk receiving stations.

(*ii*) *Chandni Power Station:* The increasing demand of the Nepa Newsprint Mill has necessitated further augmentation of Chandni Power Station. Proposals formulated for extension of the power station by a 10,000 kW generating unit at an estimated cost of Rs. one crore have since been approved. When the scheme gets implemented there will be increased production of newsprint, and the country will save foreign exchange to the extent of Rs. 1½ crores per annum.

(*E*) *Minor Schemes:*

Besides the above major schemes, proposals have already been made for installation of 16 diesel stations with an aggregate capacity of 2650 kW.

As a result of the various schemes proposed, it is anticipated that the installed capacity in the Second Five Year Plan will rise from 78220 kW in 1955/56 to 277410 kW in 1960/61.

Proposals for the Third and Fourth Five Year Plans

(*A*) *Korba Power System:*

Even with stage I extension with 150,000 kW generating capacity sets installed, a power shortage to the extent of 211,300 kW and 276,800 kW is anticipated during the years 1965-66 and 1970-71 respectively.

The increased power demand is mainly for expansion of the Bhilai Steel Factory, the enhanced target for production of coal by the National Coal Development Corporation as well as the anticipated demand of the South Eastern Railways for electric traction. Since there is a proposal for installation of a coal washery in Korba for grading of high quality coal for metallurgical and other essential purposes, about 2 million tons of coal middlings will be available annually in this area. It is therefore possible to augment the capacity thus ensuring not only economic generation but also a ready disposal of the vast quantity of middlings from the washery which it would be uneconomical to transport to other centres for any purpose. The load forecast and the combined hydro and thermal resources of the area also demand for such augmentation.

The Korba Power System is also proposed to be interconnected with the Amarkantak Power system early in Third Plan which will add 30000 kW of firm power to the combined system.

The hydro-electric power projects which are at present under investigation could then be considered for execution during the Third Five Year Plan. The Hasdo River Project and the Upper Wainganga River Project which are now under investigation have a power potential of 62500 kW and 20000 kW respectively. However the works on these two projects are not likely to be completed by the end of Third Plan. Therefore the power demand in this area during the Third Plan will will have to be catered from thermal generation with proposals as indicated above.

During the Fourth Five Year Plan, 82500 kW of power shall be available from the Hasdo River and Upper Wainganga River Projects, besides additional power from the Amarkantak system detailed below. Investigations of a few hydro electric power projects on the Indrawati Basin in Bastar district is expected to be taken up during the Third Five Year Plan and their execution in stages during the fourth and subsequent Five Year Plans. The power potential of the Indravati river basin is of the order of 1.4 million kilo watts which could be developed in stages according to power requirement during the subsequent Plans.

(*B*) *Amarkantak System*

The anticipated demand in the area will be 111000 and 169000 kW with a shortage of 44000 kW and 102000 kW during the Third and Fourth Five Year Plans respectively. Some shares of power from Rihand Hydro Electric Project of the U.P. Government is also expected during the Third Plan. Further augmentation of generating capacity to an extent of 90,000 kW from Tons River Scheme and 11000 kW from Sitarewa Projects could be made available if these schemes which are economical could be completed during the Third Five Year Plan. If for any reason the hydro electric projects do not come up as indicated above the proposed thermal station at Amlai will have to be augmented by one 75,000 kW generating unit similar to that proposed at Korba during stage I extension. The logical location of an aluminium factory in view of large deposits of bauxite, a paper mill and the development of dimond mines at Panna essentially call for adequate cheap power in these areas. The extensive coal fields will ensure economic generation and sufficient spare power for the Korba system. As such the pattern of growth of power in this area will depend upon the priority given for the thermal versus hydro schemes which are both feasible economically within a limited period.

(*C*) *Satpura-Tawa-Bhopal System*

With the proposed developments in the Second Plan as already indicated in the preceeding paragraphs the power shortage anticipated is 61,000 kW and 72,000 kW during the Third and Fourth Plans respectively. The Chambal hydro electric power though available at Bhopal by the end of Second Plan will not be appreciably available for Bhopal area due to increased demand in Madhya Bharat regions during the Third and Fourth Five Year Plans. The Tawa Hydro Electric Projects, investigation of which has been completed is expected to be completed during the Third Plan and will yield 11000 kW of power for the area. A major hydro electric project viz. the Punnassa Project, which has a power potential of 4,50,000 kW and which will benefit both the Bombay and M.P. States might not have advanced sufficiently in respect of investigation to make any power available during the Third Plan. Therefore a thermal power station of 150,000 kW is the ready answer for meeting the power shortage of the area. Economic thermal generation will be possible by location of the power station near

Barbatpur which will be interconnected with both the Tawa Hydro Electric Project and also with the Pench Valley transmission system. The system will be further interconnected with the future 220 kV transmission system proposed with the Punnassa Hydro Electric Project in the Fourth Plan linking Punnassa power project with Itarsi and thence to Jabalpur.

(*D*) *Chambal Power System*

(*i*) *Indore-Gwalior area:* The total share of power of M.P. State from Chambal Hydro Electric System is 37500 kW during the end of Second Five Year Plan and 83,500 kW during the Third Plan. The anticipated shortage of power during the Third and Fourth Five Year Plans in this area will be 16,000 kW. and 120,000 kW respectively. If the Sindh Hydro Electric Scheme with a power potential of 25,000 kW which has been proposed for immediate investigation could be completed during the Third Plan and the Chambal system is interconnected with the proposed Punnassa Hydro Electric Project at Indore with a 132 kV transmission line during the Fourth Five Year Plan, the power shortage in this area during the third and fourth Five Year Plans could be overcome. Power supply to a limited extent with the proposed Matatila Project of the U.P. Government will also be a possibility when the latter scheme develops.

(*ii*) *Chandi Power Station:* The extension of Chandni Power Station with additional 10,000 kW proposed to meet the demand of the area during the Second Five Year Plan will be inadequate eventually during the Third and Fourth Five Year Plans to the extent of 4000 and 10,000 kW respectively. It is proposed to interconnect Chandni System with Chambal System during Third Plan period by a 132 kV line and eventually with Punnassa Project. As already mentioned the Punnassa scheme if expeditiously implemented will ensure sufficient power for various regions during the Fourth Five Year Plan.

With the interconnections mentioned above the entire State Grid would have been interlinked by the end of the Fourth Five Year Plan.

(*E*) *Minor Schemes*

In view of the large area of the M.P. State it may not be possible by the end of the Third or the Fourth Plan to eliminate completely small isolated diesel stations as the grid transmission and sub-transmission lines will have yet to cover a wide area before the entire power supply could be catered for from the grid systems. It is expected that with the tempo of development and increased standard of living of the people demand for electricity will come up everywhere. As such isolated pilot stations, mostly diesel or gas engines, and small hydro electric generating units supplemented by diesel during hot weather will still be installed during the Plan to an extent of 2000 kW during each Plan period.

(*F*) *Nuclear Power Development*

Since the M.P. State is endowed with large deposits of coal (25.2% of the country's reserves) and large hydro electric potential, the necessity for development of nuclear power during the Third and Fourth Five Year Plans may not be warranted because the anticipated cost of nuclear power over conventional power may be higher so far as M.P. State is concerned.

Conclusion

In the preceeding paragraphs a brief summary of the history and pattern of power development during the pre-Plan period and at the end of the First Five Year Plan (taken as a base) has been given with the pattern of future progress during the subsequent fifteen years. It need not be stressed that the M.P. State with large natural resources could be fully developed only with adequate power resources. The power required must be developed on the basis of a phased programme and sufficiently in advance to cater for the future requirements of industries. Delay in the development of power resources will result in the shifting of industries from its logical location. Apart from retarding local development, this will not be conducive to the national interest. The plan is to start initially with thermal schemes during the time when the major hydro electric projects are under detailed investigation. The latter are then taken up for implementation and there will finally be a proper balance between thermal and hydro generation, which is the most rational and economical method of development of electric power. The State of M.P. with its strategic geographical position will ultimately form the focal point of future All India Super tension Grid interconnecting the various State Grids. It is important therefore that the various States contiguous to the M.P. State should co-ordinate and plan the future programme of electric power development to attain the objective for the all-round benefit of the States concerned. It may be hoped that this will be borne in mind when the schemes for the Third Five Year Plans are finalised.

Table—I

Physical Features of M.P.

1.	Total area of M.P.	441,209 sq. km. (14% of the country's area)
2.	Total population.	26,005,813 (forming 7.5% of the country's population)
	(a) Rural	22,861,71
	(b) Urban	3,124,098
3.	Percentage of cultivated area of M.P. to cultivated area of the country	12%.....
4.	Percentage of irrigated area to cultivated area of M.P.	5.5%
5.	Percentage of forest area of M.P. to forest area of the country.	27.2%

Principal Mineral Rescources

1.	Bauxite	44% of the country's resources.
2.	Manganese	About 50% of the country's resources.
3.	Iron Ore	About 30% of high grade ore resources of the country.
4.	Coal.	25·2% of the country's resources.
5.	Lime Stone and Doomite.	Extensive deposits of lime stone fit for cement manufacture and dolomite fit for steel Industry.

TABLE II

Power Development in Madhya Pradesh State

	1950-51			1955-56			1960-61			1965-66			1970-71		
	Public	*Private*	*Total*	*Public*	*Private*	*Total*	*Public*	*Private*	*Total*	*Public*	*Private*	*Total*	*Public*	*Private*	*Total*
(A) Number and capacity of Public and Private generating stations in M.P.															
Number of undertakings	36	23	59	47	22	69	54	7	61	50	4	54	37	3	40
Installed Capacity.	16,135 kW	18925 kW	35060 kW	56,138 kW	22182 kW	78320 kW	258093 kW	19317 K. W.	277410 kW	934550 kW	18650 kW	953,200 kW	1113,200 kW	18500 kW	1131700 kW

(B) Installed capacity of Diesel, Steam and Hydro Generating Stations in Madhya Pradesh

	1950-51	1955-56	1960-61	1965-66	1970-71
1. Diesel	9890	13,610	18,210	18,000	18,000
2. Steam	25,170	64,710	167,200	802,200	802,200
3. Hydro	—	—	92,000	133,000	311,500
Total	35,060	78,320	277,410	953,200	1131,700
(C) Per capita consumption of Electricity.	3.80 units	9.82 units	30.5 units	127.2 units	154.3 units

Review of Power Development in Assam

By G. C. GOSWAMI
Chief Electrical Engineer
Government of Assam

Prior to the First Five Year Plan period there was practically no power development scheme in the State of Assam excepting the 9 small private undertaking in some district head-quarter towns generating about 2868 kW in small diesel generating sets and 550 kW in one hydro-electric station. The railways, oil-fields and collieries accounted for about 3921 kW of installed capacity in the State.

In the year 1953-54, the 8400 kW Umtru Hydro Electric Project was taken up for constructon. 14 diesel stations under employment schemes were also sanctioned. A fullfledged department of electricity was sanctioned in March, 1955. The construction of the Umtru Hydro Electric Station and 9 employment schemes have been completed during 1958.

The State Government have also acquired the following private licencees which are now under the Electricity Department:—

(1) The Nowgong Electric Supply ..	(450 kW)
(2) The Karimganj Electric Supply ..	(350 kW)
(3) The Gauhati Electric Supply ..	(1290 kW)
(4) The Tezpur Electric Supply Ltd.	(629 kW)
(5) The Jorhat Electric Supply Ltd.	(700 kW)

The present position of power development in the State of Assam under Government is as follows:—

Umtru Hydro Electric Project ..	8400 kW
Acquired undertaking ..	3419 kW
Employment Scheme and new schemes	1714 kW
	13533 kW

A State Electricity Board has taken over the Electricity Department since June, 1958.

The following new electrification schemes have recently been approved by the State Electricity Board and construction work has just started:—

Aijal	50 kW
Jowai	75 kW
Dhekiaju	150 kW
	275 kW.

In the private sector the position regarding power development is as follows:—

Oi fields	..	10,885 kW
Railways	..	1,230 kW
Collieries	..	1,064 kW
Private Licences:		
Oil .. 2981 kW		
Hydro .. 910 kW		
		3,891 kW
		17,070 kW

Expansion Schemes

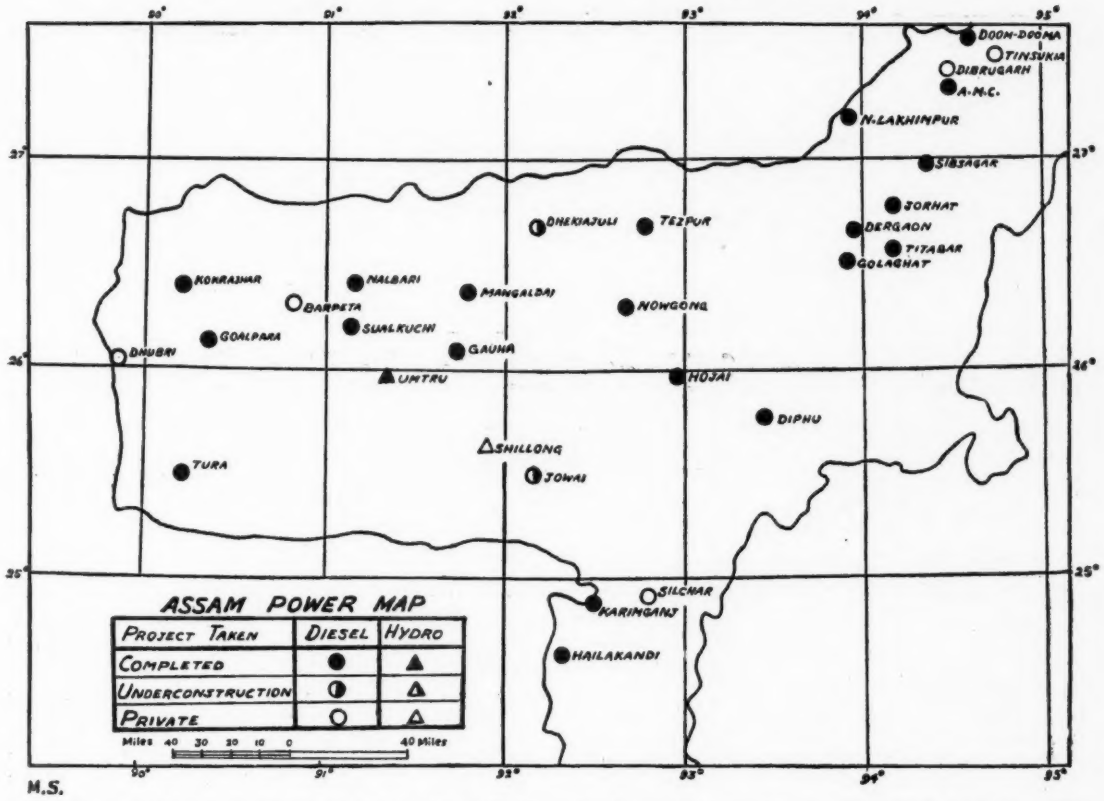
The following expansion schemes are also being taken in hand:—

A. *Installation of additional Generationg Sets.*

(1) Golaghat	..	1 × 100 kW
(2) Karimganj	..	2 × 100 kW
(3) Nowgong	..	1 × 350 kW
(4) Nalbari	..	1 × 100 kW
(5) Mangaldoi	..	1 × 100 kW
(6) Dergaon	..	1 × 100 kW
(7) Hojai	..	1 × 100 kW
(8) Goalpara	..	1 × 50 kW
(9) Doomdooma	..	1 × 256 kW
(10) Jorhat	..	1 × 456 kW
(11) Tezpur	..	1 × 200 kW
(12) Diphu	..	1 × 50 kW

B. Construction of High Tension Lines to adjoining areas.

(1) Gauhati to Rangiya	..	30 miles
(2) Doomdooma to Makum	..	10 miles
(3) Golaghat to Furkating	..	5 miles
(4) Mangaldoi to Kharupatia	..	10 miles
(5) Nowgong to Roha & Chaparmukh		14 miles
(6) Sualkuchi to Hajo	..	7 miles
(7) Dergaon to Baruabamungaon	..	5 miles



At the end of the Second Plan period, total installed capacity in the State will be as follows:—

State	..	15672 kW
Private	..	17070 kW
		32,742 kW

No account has been taken of the proposed power station (6000 kW) in the Assam refinery which is scheduled to be completed in 1960-61.

Investigation

The investigation of the Kopili Hydro Electric Project under auspices of the Central Water & Power Commission is nearing completion. In the initial stage this project can be developed for generation of 100 mW power.

In small hydro electric projects, the investigation of the Ganol Scheme in the Garo Hills for a 200 kW station is nearing completion. A small reservoir scheme in the upper reaches of the Umtru River to firm up the Umtru Station to 8400 kW and to add two additional 2800 kW hydro sets is nearing completion.

The following rivers are also being investigated for generation of power:—

(1) The Jamuna irrigation-cum-power scheme .. 6000 kW

(2) The hydro electric Scheme on the Umium river 23000 kW
(as an alternative to a 6000 kW thermal project already sanctioned for Cherrapunji area in the United Khasi & Jaintia Hills)

A scheme is also under preparation for a 20,000 kW thermal project at Naharkatiya which will utilize the natural gas in the oil-wells of the Naharkatiya Oil-fields. This is for development of the Upper Assam area around Tinsukia.

Remarks

At the beginning of the First Five Year Plan, the per capita consumption of electricity in the State of Assam was only 0.56 kWh. At the end of the First Five Year Plan, the per capita consumption rose to 0.97 kWh. Under the present arrangement, the per capita consumtion of electricity in Assam will only rise to 5 kWh at the end of Second Five Year Plan.

Assam is the most backward State in industrial development although raw material coal, natural gas, limestone, valuable timber and forest etc. are abundant in the State. It is expected that with strengthening of the railway line and opening of the railway bridge at Pandu, the State will be opened up for industries and along with the finalisation of the plan for industrial development of the State, the power projects under investigation will be ready to deliver the power without which no industry can be started.

The State Electricity Department has provided a nucleus for power station in practically every district and subdivisional headquarters including several large villages in the hope that when large supply of power is available, all the important towns and villages can be inter-connected in a grid to the nearest power station.

Development of Electricity in Andhra Pradesh

By V. PARVATHESAM
Superintending Engineer Tech. (Electrical)
Government of Andhra

The progress achieved in the field of electrical development since the formation of Andhra Pradesh on 1.11.1956 is gratifying.

The total provision against Power Projects as finally approved by the Planning Commission and Government of India, during the second Five Year Plan period is Rs. 27 crores, of which Rs. 21 crores is for Andhra area and Rs. 6 crores for Telangana. Against this, an amount of Rs. 19 crores has been spent so far in about half the Plan period and the expenditure constitutes 70 percent of the total outlay for the five years. Of the Rs. 19 crores of expenditure, as much as Rs. 15 crores has been spent since the formation of Andhra Pradesh—Rs. 4 crores in Telangana and Rs. 11 crores in Andhra.

Over 500 towns and villages were electrified since 1.11.1956 Before Andhra Pradesh came into being, only about 20 villages and towns in Telangana were electrified. Now there are about 130 villages electrified and another 100 will be electrified in the current year. In the year 1957-58, 257 towns and villages in Andhra and 103 towns and villages in Telangana have been electrified and that is the highest rate so far achieved for the two regions. By the end of the current year there will be a total of 1,500 villages and towns electrified in the State. That i nearly double the number as on 1.11 1956.

The gross revenue on Electricity schemes which was about Rs. 2·5 crores per annum on 1·11·1956 has been doubled and in 1958-59, the gross revenue from Electricity schemes is expected to be of the order of Rs. 4.5 crores.

The installed generating capacity has increased from 94,000 kW to 160,000 kW.

The installed capacity of 51,000 kW at Machkund Power Station will be increased to 114,750 kW when the second stage works now in progress are completed by about the end of 1958-59.

The first stage works of Tungabhadra Hydro-Electric Scheme have all been completed with four machines of 9000 kW each. The second stage comprising addition of another four sets will be taken up immediately after the required foreign exchange is released by the Government of India. If the necessary foreign exchange is made available in time, it is anticipated that the second stage works will be completed by about 1960-61 i.e. end of the current Plan period.

The above Hydro Stations are now supplying power to Andhra area. Machkund Station is now fully loaded up and Tungabhadra Station will also be loaded up shortly.

Although the progress so far achieved in the matter of electrical development is outstanding, the demand for power continues to be greater than the availability in the State. The load survey recently carried out by the Central Water and Power Commission in consulation with the Electricity Department has established a probable power shortage of 60,000 kW by end of the second Plan period (i.e.) 1960-61. To obviate this anticipated power shortage, the Upper Sileru Hydro Electric Scheme First Stage is contemplated to be taken up for execution and Government of India has been addressed to accord technical clearence and approval for the scheme.

The Upper Sileru Hydel Project is considered the cheapest of all post-war projects. The cost per kW installed here will be Rs. 500/600 whereas on other recent project, it ranges from Rs. 1500 to 2000. It is anticipated that most of the civil works and major portion of the work of erection of machinery may be completed by about 1960-61 and Sileru Power made available in 1961-62 if the sanction of Government of India is accorded early and foreign exchange allotted.

The Ferromanganese factory at Garividi, Oil Refinery at Visakhapatnam, Cement Factory in Mangalagiri have all been extended supply. Their full quota

of power will be made available when the Machkund Second Stage Works are completed.

In Telangana, the Ramagundam Thermal Station has been comissioned with an installed capacity of 37,500 kW.

The transmission lines to Sirpur and Warrangal have been completed and arrangements are being made for extending supply to the block loads like paper mills, collieries, cement factories and textile mills. The 66 kV line between Ramagundam and Hyderabad is expected to be completed shortly.

This line provides the inter-connection between Ramagundam Power Station and Hyderabad. Power to the extent of about 5000 kW can be supplied to the twin cities through this line, thus relieving the acute power position in the cities.

A comprehensive scheme for Telangana has been prepared and is under the consideration of Government. It envisages extension of transmission lines to all important places to facilitate rural electrification. There are also proposals under consideration to interconnect Andhra and Telangana Regions and thus establish an integrated grid for Andhra Pradesh. When this integrated grid is established, it will be possible to utilise the different power sources in the State in a co-ordinated and economic manner, meeting the power shortage in one region by the surplus power in the other region and thus have overall economy.

The distribution system in the Hyderabad and Secunderabad cities is being converted from 3.3 kV to 6.6 kV system so that a greater number of consumers may be catered to. A 33 kV ring main will also be established to reinforce the distribution system and improve the regulation. An additional boiler is also proposed to be added at Hussainsagar Thermal Station where the inadequate steam capacity is causing a bottleneck. Foreign exchange for this is already secured as this scheme is in the 'core' of the plan. A 66 kV line is being erected between Erragadda and Hussainsagar for increasing the capacity of interconnection. The present tie line between them is at 6.6 kV and is found inadequate for transferance of power. Over 500 to 600 services are being released per month in the twin cities.

Rural electrification is given special consideration. It is of great importance to our country. About 80 per cent of our population live in villages. Electricity in rural areas can serve as an economic tool and adapt itself to improve the condition of the villages. Lift irrigation and cottage industries are the major items for which electricity can be utilised in the rural areas. By extending amenities, hitherto available in the cities, to the villages also, the tendency on the part of the villagers to move towards towns can be avoided. The earning capacity of our villagers can be increased by increasing employment during the periods when there is no cultivation.

At the beginning of the second Five Year Plan period, about 700 towns and villages only had electric supply. This number is expected to be raised to about 2000 villages by the end of the Plan period, by laying special emphasis on rural electrification and stepping it up. This constitutes a substantial progress. But this figure of 2000 is only a small percentage of about 26,000 which is the total number of villages and towns in Andhra Pradesh.

The percapita consumption of electricity is now recognised as an index of the economic development of any country. It was about 7 at the beginning of the second Five Year Plan period for Andhra Pradesh. This is now about 10 and is expected to increase to about 15 by the end of the second Plan period. While this is by itself a substantial progress, the leeway yet to be made by Andhra Pradesh can be known when we take into account the per capita consumption of our neighbouring States which is about 30 for Madras and 40 for Mysore and the figures of more advanced countries which range between 1000 to 4500.

Andhra Pradesh is endowed with immense hydro electric power potential. The State's total power potential is estimated approximately as 3 million kilowatts. Detailed investigation of the Upper Sileru Hydro Electric Project was completed and the scheme has been finalised. The scheme report is now under the scrutiny of the Planning Commission, Government of India. The ultimate installed capacity at this project is 300 MW and under the 1st stage which is included in the Second Five Year Plan, 120 MW of installed capacity will be achieved.

The Lower Sileru Project, which is estimated to have a power potential of over 300 MW, is under detailed investigation, which is expected to be completed by about the middle of 1959-60.

The report on the Nagarjunasagar Hydro Electric Project is being prepared. The scheme is estimated to yield over 75 MW of firm power and 300 MW of seasonal power.

Detailed investigation of the Srisailam project with a power potential of 420 MW. will be taken up shortly and the report finalised before the end of the second Plan.

There is therefore large scope for electrical development in the State. Necessary steps are being taken to step it up and thus lay the foundation for greater industrial development and prosperity in the rural areas.

Power Development in the Punjab

By S. HARBANS SINGH
Sales Engineer
Electricity Branch (South) P.W.D. *Punjab*

Realising the necessity of cheap electric power for the allround development of the country, the Punjab, far removed from coalfiels as it is, had to turn to the exploitation of water sources for the generation of power for meeting the requirements of the industrial development in the State. After completing preliminary surveys, work on the Uhl River Hydro Electric Scheme was undertaken during 1927 and with its completion in 1933, the Punjab was for the first time indicated on the hydro electric map of the country. This scheme continued to meet the requirements of the areas in the Central Punjab till the division of the country in 1947 when the power house, with a major portion of the transmission system fell to the share of the Punjab (India). At that time, out of the maximum demand of 28,000 kW recorded on this system, only about 10,000 kW were being utilised in Punjab (India) and the balance was being used in Punjab (Pakistan). At that time, this scheme was serving only the Western and Northern areas of Punjab, namely, Kangra, Gurdaspur, Amritsar, Jullundur, Ferozepore and Ludhiana Districts and that too mainly the important urban areas. The Eastern and Southern parts of the State had no such project and the requirements of the major towns were being met by about two dozen private electric supply undertakings having diesel generating power houses of small capacities.

Even before partition in 1947, the Punjab Government had realised that the Uhl River Scheme was not capable of meeting the growing demands especially of of the industries and after having completed preliminary surveys, the work on the Bhakra Nangal Project was taken in hand in 1945. The partition followed by migration of millions from across the border created a tremendous problem in resettlement of the refugees. Industrial development was one major step in this direction. Grow More Food Compaign was another problem facing the country at that time and it was realised that electricity was a basic necessity for solving all these problems. Accordingly, the work on the Bhakra Nangal Project was taken up at top speed and at the same time, the scope of the Project was altered and enlarged to meet the requirements of all the areas not covered by the Uhl River Scheme, the Northern areas of Rajasthan and all the areas of the erstwhile Pepsu State. Simultaneously the power from the Uhl River Scheme was extended to the surrounding areas as far as possible and as the load from these areas developed, the demand of Pakistan was reduced successively, the supply having been completely stopped with effect from February, 1958. To meet the immediate requirements of Eastern and Southern regions of the State, Government installed steam plants at Panipat and Jagadhri and diesel sets at Palwal, Bahadurgarh, Chandigarh etc. These plants not only catered for the immediate reqirements of industries and agriculture and greatly fecilitated the-re-settlement of refugees, but also helped in providing ready load for the Bhakra Nangal Project.

Second of January, 1955, was a great day in the history of Punjab as also in the history of India; on that day the Rashtrapati inaugurated and commissioned the first power house of the Bhakra Nangal Project at Ganguwal with two generators of 24,000 kW each which provided a great relief to the overloaded Uhl River Scheme and also the Eastern and Southern parts of the State which had been electricity starved till then. With the commissioning of this power house, the installed hydro capacity in Punjab increased from 48,000 kW of the Uhl River Scheme to 96,000 kW. Another step forward in the development of hydro electric sources in the State was the commissioning of an exactly similar second power house of the Project at Kotla in June, 1956. With the commissioning of this power house, the installed capacity of hydro electric stations in Punjab increased to 144 mW with a firm capacity of 102 mW.

In view of the projected Bhakra Nangal Scheme, the Government of the joint Punjab had decided before partition that the licences of the private electric supply undertakings should not be renewed after their expiry and that the undertakings should be taken over

by Government. This policy continued to be pursued by the Government of Punjab (India) after partition and in pursuance of this policy the Government have already taken over 11 electric supply undertakings. At present, there are two electric supply undertakings owned by the Municipal Committees at Amritsar and Simla and there are 15 private electric supply undertakings including three located in the erstwhile Pepsu State areas. Except for two of these undertakings all others have been given bulk supply from the Bhakra Nangal Project. As a result of this bulk supply, Government have been able to persuade the licensees to adopt more or less a uniform tariff at least for general supply. It is a matter of great satisfaction that the rates for general supply in the areas of all these licensees are practically the same and are only very slightly higher than the Government tariffs.

For distributing the power available from the Uhl River Scheme and the Ganguwal and Kotla Power Houses of the Bhakra Nangal Project, the Electricity Department of the Punjab Government had to provide a vast net-work of transmission and distribution lines. The length of transmission lines and grid substations of voltages of 33 kV and above completed so far and under construction are given below:—

	Length of Transmission Lines (Miles)		*No. of Sub-stations.*		
Voltage	*Completed*	*Under construction or to be completed by* 1961	*Completed*	*Under construction*	*To be completed by* 1961
33 kV	1023	369	58	30	10
66 kV	141	224	5	7	-
132 kV	276	160	12	5	-
220 kV	220	220		-	4

It is a matter of great pride and satisfaction that all these lines have been erected by the Electricity Department without the aid of any outside agency, foreign or Indian. The erection of these works departmentally has resulted in a saving of crores of rupees to the State.

In the field of distribution, very remarkable progress has been achieved. At the time of partition, there were only about 50 towns and villages served by the Government Schemes and there were only about 50 tubewells worked by electricity throughout the State. By the end of First Plan, the number of towns and villages electrified had increased to 833 and the number of agricultural connections for irrigation purposes to 3838. The achievement during the first two years of the Second Five Year Plan has been still more remarkable; by the end of 1957-58, the number of towns and villages electrified had increased to 1743 and the number of tubewell connections to 7165. The number of general (including public lighting) and industrial (including bulk) consumers served by Government stood at 233,552 and 8109, respectively with a total connected load of 262, 724 kW including the tubewells. For extending electricity to all these areas, the Department had to lay a vast net-work of 11 kV and L. T. lines. 3,000 miles of 11 kV lines and 1900 substations of 11/0·4 kV having an installed capacity of 151,000 kVA had been installed during the first Five Year Plan. During the first two years of the Second Plan, 1000 mils of 11 kV lines and 980 substations of 11/0.4 kV with an aggregate capacity of 52,000 kVA had been added to the system. The capital outlay on the local distribution schemes stood at about Rs. 13 crores by the end of 1957-58 and itis proposed to spend about 2.5 crores during the financial year 1958-59.

The capital outlay on Uhl River Scheme upto 31. 3.58 had increased to Rs. 11.55 crores as against Rs. 5.66 crores at the time of partition. The Ganguwal, Kotla and Left Bank Bhakra Power Houses are estimated to cost Rs 59. 26 crore excluding a sum of Rs. 10 crores as the proportionate cost of civil works, which has recently been decided to be debited to the electrical portion of the Project. The transmission system envisaged under the Bhakra Nangal Power Project is estimated to cost Rs. 26.97 crores.

Since the beginning of the First Plan, vast relaxations have been made in the commerical policies of the Department. Formerly, for working out financial justification of new estimates, the monthly return was based on 1/60th of the capital cost; now this is based on 1/100th for urban and 1/120th for rural consumers. Similarly, the basis of annual minimum consumption guarantee was reduced from 20 percent to 10 percent which remained in force till the end of 1856. However, with effect from 1.1.57, a flat rate of Rs. 60/- per B.H.P. per year was introduced for M. C. G. which, in the case of most of the rural connections, represented further reduction in the amount of annual M. C. G. Recently, the service rentals for long lines have also been reduced considerably. These relaxations in the commercial policies have been very helpful in the extension of electricity into rural areas and it has been possible for the rural population to go in for electric connections without paying anything towards the capital cost of the lines.

Future Development

As would be noticed from the figures given above, the achievements of Punjab Government in the field of power development are quite remarkable. The development has, however, been impeded by two main factors, namely, shortage of power and capital. So far as availability of capital is concerned, Punjab being a small State and not being very well off financially, has to depend mostly on loans from the Centre, though, of course, the profits of the Uhl River Scheme have been ploughed back into the schemes of extending electricity into new areas. In the matter of generating capacity, Punjab has not been in a very happy position. When the Bhakra Nangal Power Project was taken in hand, it was felt that the power available from four machines installed in Ganguwal and Kotla Power Houses would be quite sufficient for a number of years. This feeling was based on the rate of load development on the Uhl River Scheme, which, though commissioned in 1933, was running below the firm capacity of 33,000 kW even upto the time of partition in 1947. However, to assess the load potential-

ities, an initial survey was carried out by a Load Planning Officer of the Department in 1950. The Bhakra Control Board, who are in over-all control of the construction of the project, felt that there should be a systematic and more detailed load survey of the areas to be served by the Uhl River Scheme and the Bhakra Nangal Projects so that the generating capacity could be phased accordingly. The work was accordingly entrusted to Central Water & Power Commission who carried out a detailed load survey of the Punjab, Pepsu and the areas of Rajasthan to be served by the Bhakra Nangal Project, during 1952. In this survey the Central Water & Power Commission was assisted by the officers of the States concerned. By 1955 it had come to be realised the the figures of load forecast as indicated in the survey carried out in 1952 were not in consonance with the actual load development and accordingly another load survey was carried out by the Commission in the year 1955.

Load surveys porvide a very important basic data which is normally the guiding factor in determining the progressive provision of generating capacity and transmission system so as to make the project most economical. From an economist's and a financier's point of view, this is the correct line of thinking. In Punjab all the big hydro electric projects are State-owned. As elesewhere, the rule of productivity has been the major factor in deciding the generating capacity and has been strictly adhered to by the Government and the Bhakra Control Board who are in over-all chrge of the construction of the project. The financial results and the productivity can be worked out correctly after the load that would come on the system is known to a reasonable degree of accuracy ; and this can be assessed by load surveys only and it is here that the importance of correct load surveys comes in. An over-optimistic load survey would mean unnecessary and avoidable expenditure on generation and transmission which, according to the actual development, may not prove productive and economical. In such a case, however, only a part of the expenditure incurred on generation and transmission would be unproductive and the actual loss per annum would be interest, depreciation and maintenance amounting to about 7.25 prcent of the capital cost. On the other hand, a conservative load survey would result in inadequate generating and transmission capacity being provided and the effect would be disastrous for the regions to be covered by the project because it will hamper and impede allround development, i.e. development in the field of industries, agriculture, commerce etc. The over-all loss to the region in such a case consists of:

(*i*) machinery installed and/or procured by various industries, remaining un-utilized and resultant burden on the industries on account of interest, depreciation and maintenance of such machinery ;

(*ii*) loss of production, agricultural as well as industrial

(*iii*) loss to State taxes on products of the industries ;

(*iv*) resultant unemployment.

The result of this loss would be far greater than that resulting from the provision of extra capacity in generation and transmission. Such a loss would be in addition to the mental and physical worry caused to the prospective users of power in various fields which can hardly be assessed in terms of money. The loss of production, referred to above, not only undermines the national morale an creats sources of corruption but also sets in motion a chain of reactions including,

(*a*) demand exceeding availability;
(*b*) increase in prices ;
(*c*) increase in imports ;
(*d*) foreign exchange difficulties etc. etc.

Punjab has been an unfortunte victim of conservative load surveys and consequent short-fall of generating capacity as compared to the actual requirements. The following table shows the figures of the maximum demand of Punjab areas excluding the erstwhile Pepsu areas anticipated according to the 1952 and 1955 load surveys:—

Year	*Anticipated Maximum demand (kW according to Load Survey*			
	1952	1955		
Year		*Day*	*Night*	*Remarks*
1955-56	42,700	52,400	43,700	
1956-57	48,800	66,000	51,600	
1957-58	61,900	78,000	61,600	
1958-59	66,620	93,500	71,100	
1960-61	71,200	110,900	80,100	
1965-66	90,500	146,200	100,700	

From the above table, it would be seen that though there is not much difference between the figures of 1952 load surveys and those of 1955-56 for the night demand, the figures for day demand under the 1955 load survey are appreciably higher than those under 1952 surveys. The difference increases from about 25% in the initial years to about 60% during 1965-66. The actual development of load, as has been experienced in Punjab, is far greater than even the load forecast under the 1955 load surveys. The maximum demand on Uhl and Bharkra Nangal Power Projects by the end of 1957-58 was 124,000 kW. Out of this, the demand of Delhi was 20,000 kW ; of Jammu and Kashmir Government 2,500 kW and of Himachal Pradesh about 500 kW. The demand of erstwhile Pepsu areas was 8,000 kW. Allowing for a diversity factor of 1.1, the maximum demand of the Punjab areas including the Bhakra Dam construction but excluding the areas of erstwhile Pepsu State, works out to 96,000 kW. This demand is experienced during the night hours between 7.00 P. M. and 9.00 P. M. Against this, the maximum demand of Punjab areas anticipated by the end of 1957-58 according to to the 1955 load survey for night was 61,000 kW. The demand of about 96,000 kW from Punjab areas or about 104,000 kW of Punjab and erstwhile Pepsu areas has been experienced inspite of the following factors which had a great retarding effect

on the development of load and consequently reduced the demand registered on the system:—

(*i*) Since about the middle of 1956, when it came to be realised that the development was much faster than anticipated, industrial connections have not been and are not being given freely. Except for connections in rural areas upto 10 B. H. P., all industrial loads in the urban areas and in rural areas above 10 B. H. P. are sanctioned by a central committee constituted for the purpose.

(*ii*) Most of the industrial connections given since 1956, both in urban and rural areas, are not allowed to run druing the peak load hours in the evening. In the biggest industrial areas of Punjab, namely, Amritsar, Jullundur and Ludhiana, most of the industrial connections during the last about two years have been sanctioned for working during either the off-peak hours or night hours only.

(*iii*) In the case of large industries like Shri Gopal Paper Mills, Surajpur and Dadri Cement Factories, Jagatjit Textile Mills Phagwara, textile mills at Bhiwani and Hissar etc., it has not been possible so far to meet their full demand and only partial supply is being given. If ample power were available, immediate addition in the demand from these few industries would have been about 10,000 kW.

(*iv*) During the last about two years, supply of power has been refused to a couple of steel furnaces at Jullundur and Ludhiana requiring about 8,000 kW., a textile mill at Rajpura requiring 3,000 kW and a few other large industrial consumers.

(*v*) The demand of the licensees to whom bulk supply is being given from the Bhakra Nangal Project, is not being met fully. If power could be supplied to them freely, their demand would have been at least 8,000 kW more than what it is now.

(*vi*) Due to shortage of power, the rate of grant of connections has been slowed down appreciably. The load of the applications pending with the Department is more than 220,000 kW excluding the demands of large industrial consumers and licensees mentioned above.

It is amply clear from the facts given above that the demand assessed according to the 1955 load survey is very much on the conservative side as compared to the actual load development experienced up-to-date, This is a situtation for which none can possibly be blamed because the rate of development has been so phenomenal and unprecedented that the increase in demand could not be assessed correctly according to the conventional methods of load survey. The author has been directly connected with the load development in Punjab during last about six years which has been the most important period in the matter of development of electric power and is convinced that the load surveys must be based on the actual development that has been experienced in any particular region after the availability of supply in abundance in recent years, because if the actual devopment is not taken into consideration theoritical principles of assessment are likely to continue misleading us as has happened in the recent past. The Central Water & Power Commission are present compiling load data for the whole country. According to their assessment, the maximum demand of Punjab State including the erstwhile Pepsu areas, has been assessed by them as 154 mW by the end of the Second Plan as compared to the existing demand of 104 mW. The author, in his capcity as sales engineer, had the occasion to study this assessment and also to make an assessment of the Punjab demands keeping in view the actual development so far, the demands registered with the department by various types of consumers and the anticipated demands during the remaining part of the Second Plan. As a result of this scrutiny, it has been estimated that if ample supply were available, the additional demand of Punjab during the peak load hours upto the end of the Second Plan would be 130 mW, thereby raising the total demand of Punjab to 234 mW which is over 50% higher than the assessment made by the Central Water & Power Commission.

On the basis of the figures of maximum demand anticipated according to the 1955 load survey and the demand of the Nangal Fertilizer Factory, the Punjab Government was allowed to go ahead with the installation of five units of 93,000 kW each in the Left Bank Bhakra Power House and one additional unit of 29,250 kW in each of the two Power Houses at Ganguwal and Kotla. The additional firm power available from these units, keeping one unit in the Bhakra Power House as standby, would be 270 mW. Out of this additional power, 160 mW are to be supplied to the Nangal Fertilizer Factory, additional 40 mW to Delhi and 22 mW to Rajasthan as their share out of the available power from the common pool. By the end of the Second Plan, the additional demand of Jammu & Kashmir and Himachal Pradesh would be 7 mW and after meeting all these demands, the power available for Punjab would be only 41 mW. Against this, the additional demand of Punjab upto the end of the Second Plan has been assessed as 130 mW. It is thus abundantly clear that even after the installation of the above additional units, the power available to Punjab would fall short of the anticipated demand by 98 mW. The picture for future power development in Punjab is thus extremely gloomy. As explained above, there are, at present, number of restrictions on the working of industrial consumers and new loads are sanctioned with great care and thought after detailed scrutiny. Not only these restrictions have to continue but in fact more drastic restrictions may have to be resorted to if other sources of power are not tapped immediately and additional power made available for distribution.

There is a provision for additional four units in the Right Bank Bhakra Power House which can provide additional 212 mW of firm power. No decision has so far been arrived at with regard to the installation of these units. It has been experienced that from the date of decision upto the date of commissioning of the generating plant, it takes easily five years. Even if a decision is taken, say by the end of 1958-59 the earliest additional power from the Right Bank Power. House can be available, would be by theend of 19 63-64

In other words, this means that from now upto the end of 1963-64 the industrial development will have to be very much restricted and the result would be disastrous for the economy of the State. Already Punjab has lost many industries and industrialists as a result of partition and if the budding and future industries are forced to go out of the State for non-availability of power, this would be another very big blow to the economy of the State. Assuming a very reasonable and rather conservative figure of 40 mW for yearly increase in the maximum demand of Punjab areas, the additional maximum demand during the first three years of the Third Plan would be 120 mW. Adding to this the additional demand of 130 mW from now upto the end of the Second Plan, the additional demand of Punjab upto the end of 1963-64 would be 250 mW. As explained above, the additional power available to Punjab upto the end of Second Plan would be 41 mW; out of the 212 mW available from the Right Bank Bhakra Power House, the share of Punjab would be 180 mW thus providing a total of 221 mW to Punjab upto the end of 1963-64 by which time the Right Bank could be commissioned assuming that it is sanctioned now. It would thus be seen that even after the commissioning of the Right Bank Bhakra Power House, the demand of Punjab would exceed the available power by 29 mW by the end of 1963-64. The situation thus calls for immediate survey of additional sources of power in the State. Having studied the load development minutely, the author is of the firm belief that for the next about 15 years, there is hardly any necessity of any load surveys in the region. All efforts must be directed towards utilising whatever power is availble according to the schemes in hand and further sources of power should be surveyed and works taken in hand immediately. The reason generally given for not sanctioning new schemes is the shortage of funds but it must be realised that in such big schemes, planning has got to be at least about 10 years ahead and unless action is taken immediately the entire planning in the region is bound to be upset and the inhabitants of the region would suffer a geat economic set-back. In any such scheme, practically no foreign exchange would be required at the initial period during which the civil works have to be carried out as plenty of machinery for any new scheme would be available as soon as the work on the Bhakra Dam is completed about a year and a half hence. The foreign exchange element would only come in for the purchase of heavy machinery for the power houses; even a part of that may be available in the country, namely Heavy Electrical Factory coming up at Bhopal, by the time the machinery is actually required. But even if some machinery has to be imported, the cost thereof would not be very heavy and in fact would be negligible compared to the direct and indirect benefits accruing to the people and the State from the increased agricultural and industrial production. A bold decision in the matter is, therefore, immediately called for.

Another important point that needs serious consideration is the provision of a sufficiently big thermal plant as a part of the project. Such a plant will not only firm up the capacity of the hydro project by taking peaks of the system and sharing system load during periods of short water supply, but will also provide a very useful standby plant in case of emergencies, which cannot safely be ignored and overlooked. The cost of generation from a steam plant with 4 or 5 units of about 40 mW each set up in the vicinity of Delhi, would be in the neighbourhood of 4·5 NP per unit. Against this, the cost of generation from an atomic power station had been estimated to be 0.7 pence or 4 NP for G. E. C. 360 mW nuclear power station designed in the beginning of 1957. It is quite likely that with rapid advance in nuclear power engineering, the cost of generation may come down to 3.5 NP.The generation from such a power station if located near a big load centre like Delhi, would compare very favourably with steam generation and even hydro power from Bhakra power houses, for which the present grid rate for purchase from the common pool works out to roughly 4.5 NP. A nuclear power station of about 250 mW located in the vicinity of Delhi and working as a part of the Bhakra Nangal Power Project would thus appear to be a very good proposition and in fact the real answer to the power shortage envisaged in the region even after all the power potential of this biggest project has been harnessed.

Indian Journal of

Power and River Valley Development

Annual Subscription : Rs. 20, $6 £2

Single copy : Rs. 2

Managerial & Editorial Office :

6/2, Madan Street, Calcutta - 13

Power for Prosperity: The Chambal Valley Development Scheme

This multipurpose project, after its completion will produce 2,15,000 kW of electrical energy and store sufficient water to irrigate 14 lakhs acres of land in Rajasthan and Madhya Pradesh and contribute con siderably to the economy of the two participating States. The features of the power sector of this scheme are briefly outlined in this article.

K. S. SIVAPRAKASAM
Superintending Engineer Electrical
Chambal Hydel Project

The power development in the country has received an impetus on account of the industrial policy laid down in the successive Five-year Plans. Many river valley projects are under execution since the country attained independence. The Chambal Valley Development Scheme is one such multipurpose project in the core of the plan and its execution is jointly undertaken by the two Governments of Rajasthan and Madhya Pradesh. This project will contribute its share towards the development of power and irrigation in the country.

The present demand for power in India is said to be 3.42 million kW of which 0.96 million kW is met by hydel power and 2.46 million kW by thermal and other sources. The power demand in the country is increasing phenomenally. By the end of the Second Plan period the demand is likely to touch the figure of 6.94 million kW which is proposed to be met by additional hydel and thermal installations.

The Chambal Project will add 2,15,000 kW at 60% load factor to the country's existing resources. It will also contribute to the production of 4,75,000 tons of food grains by irrigating 14 lakhs acres of arable lanp in the two States of Rajasthan and Madhya Pradesh. Also the per capita consumption of electricity in Madhya Pradesh and Rajasthan is expected to rise by 21.6 and 35.3 kWh respectively. The direct income from the sale of energy in bulk at the high voltage sub-stations will be about 5.66 crores.

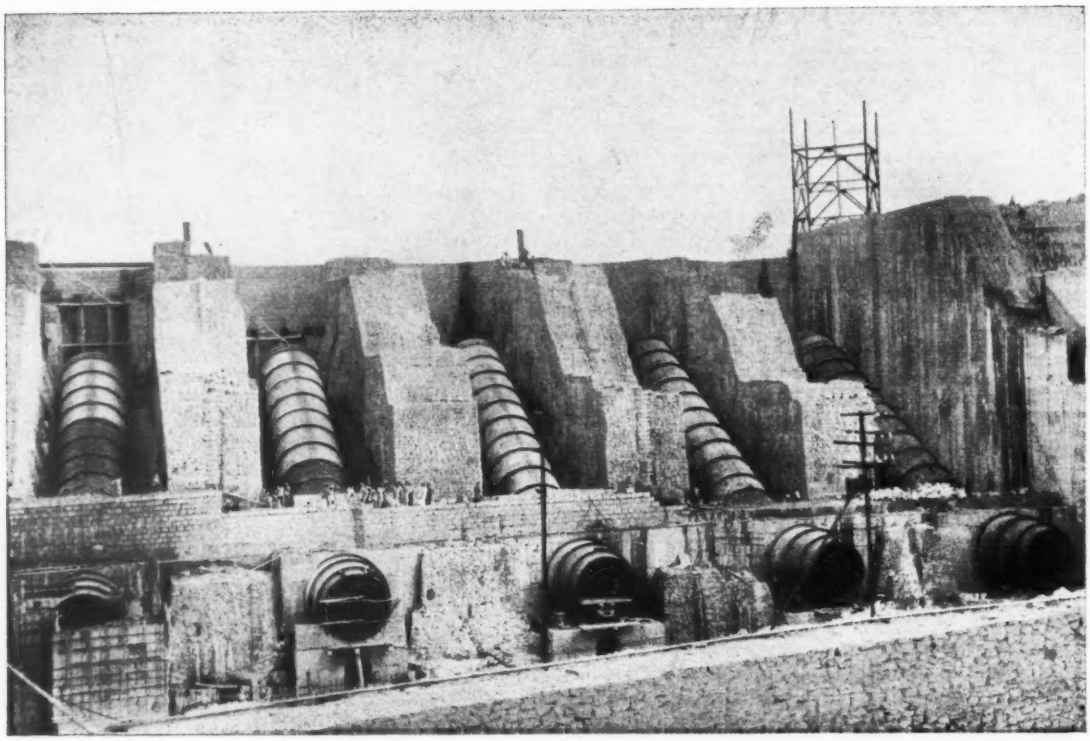
Table I

Particulars		1950-51 *pre-Plan period*	1955-56 *end of 1st Plan period*	1960-61 *end of 2nd Plan period*	1965-66 *end of 3rd Plan period*	1970-71 *end of 4th Plan period*
Estimated total of simultaneous demand in kW	Madhya Pradesh	7358	9215	52,238	115,500	216,691
	Rajasthan	10,200	16,809	69,552	122,714	204,559
Firm power available kW	Madhya Pradesh	6525	21,474	54,936	95,000	*
	Rajasthan	30,800	*	113,200	*	*
Power surplus or shortage(-) in kW	Madhya Pradesh	(−) 833	12,259	(−) 2,698	(−) 20,000	*
	Rajasthan	(−) 20000	*	(−) 43,648	*	

* Figures not available

The load survey conducted in the two States by the Central Water and Power Commission in 1956 (table 1) also points out to the immediate necessity for installation of new power plants to meet the growing demand in this region.

The position of power demand in the Chambal Project area at the end of the first, second, third and fourth Plan periods is illustrated in fig. 1. The supply



Penstocks under construction

and demand position in 1960-61 onwards also include the hydel power from the Chambal Valley Development Scheme as well as the extensions to Gwalior and Indore thermal power stations, etc.

The benefits that accrue from the Chambal Valley Development Scheme and the costs towards the common works such as the Gandhisagar Dam, Gandhisagar Power Station, the Kotah barrage and the common carriers of power and water are to be shared fifty-fifty by the two States. The Chambal Project is planned to be completed in three distinct stages.

The first stage of development consists of the construction of the Gandhisagar Dam and power house across the river Chambal at a site 4½ miles downstream of the historic Chourasigarh Fort, the construction of the Kotah barrage 1/2 mile upstream of Kotah City, 300 miles of irrigation canals, 527 miles of 132 kV, and 66 kV transmission lines in Madhya Pradesh and 402 miles of 132 kV transmission lines in Rajasthan with several high voltage step-down sub-stations. Four generators of 23,000 kW capacity each will be installed at the Gandhisagar Power Station during the first stage with provision for a fifth one to be installed at a later stage. The firm power available from Gandhisagar Power Station will be 80,000 kW at 60% load factor.

The second stage of development envisages the construction of the Ranapratapsagar Dam and power house at Ravatbhatta, a place 20 miles downstream of the Gandhisagar Dam with necessary extensions to the transmission system. Power generated at Ranapratapsagar by the installation of four units of 28,000 kW each will add a firm capacity of 90,000 kW at 60% load factor.

The third and the last stage provides for the con-

Fig. 2

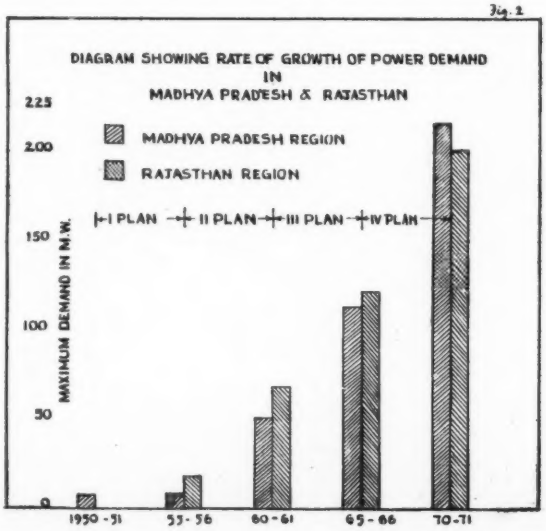
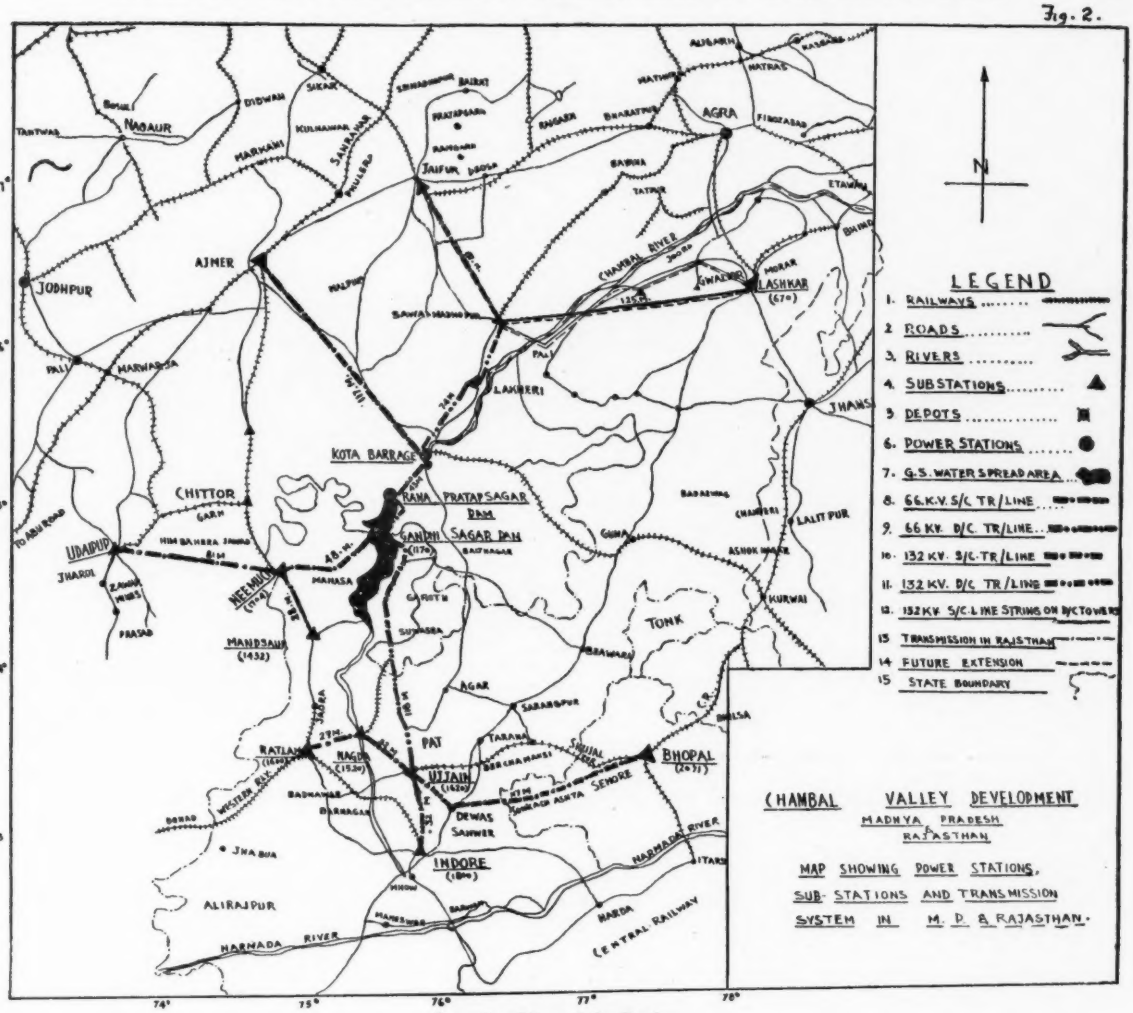


Fig. 2.



Location Map of the Project

struction of yet another dam with a power house, upstream of Kotah city. Though the power house details have not yet been finalised the firm power available from this station is estimated to be 45,000 kW at 60% load factor.

Thus, the power available from the Chambal Valley Development Scheme after completion of the three stages would be 2,15,000 kW at 60% load factor.

Water for power generation at the Gandhisagar Power Station is drawn from five steel penstocks, each 15'6" diameter and 136 feet long, embedded in the dam. Four of them are to be used in the first stage and the fifth one at a later stage. Suitable penstock gates and trash racks for all the five penstocks have however, been provided for regulating and controlling water-flow through them to the turbines.

The Power station will be housed in a building 311'×59'×75'. Provision is made for five generating units spaced 50 ft. apart. At present four units are being installed. The fifth unit may be installed later on.

Of the four vertical shaft Francis type turbines to be installed, three are supplied by M/s. Voith of Germany and the fourth by M/s. Hitachi of Japan. Each turbine is capable of developing 34,000 HP at a mean operating head of 149 ft., the head varying from a minimum of 125 ft. to a maximum of 187 ft.

Each one of the three Voith's turbines is direct coupled to a vertical shaft, umbrella type, Siemens 'Electrical shaft' generater, rated at 23,000 kVA and unity power factor. The fourth unit is of the Japanese make and of the same rating. The voltage of generation is 11 kV and the synchronous speed of the unit is 187.5 r. p. m. The generators are star connected with the neutral isolated.

The special features of the Siemens generators are

FIG. 3.

Showing Location of Carrier Communication and VHF Radio Equipment

the electrical shaft system of excitation, the magnetic amplifier type voltage regulators and the neutral isolation.

A transmission voltage of 132 kV having been slected, the stepping-up is done by the use of 12 nos. of single phase transformers each rated at 7667 kVA $11/132/\sqrt{3}$ kV 50 c/s forming four banks and connected $\triangle - Y$. These transformers are from M/s. Mitsubishi of Japan.

The H. V. circuit breakers are of the low oil content type and are being supplied by M/s. G. I. E. of Italy and M/s. Asea, of Sweden. Unit type switching arrangement is adopted on the LV side and duplicate or hospital bus arrangement is provided on the HV side.

The transmission system of the Chambal Valley Development Scheme is extensive. It has a total of 929 circuit miles, in 132 and 66 kV high tension lines, as shown in the index map, fig.2. Carrier and VHF communication is to be employed for the operation and maintenance of this extensive transmission system. The carrier system is intended for communication between sub-stations whereas the VHF radio communication is to be utilised to contact the operation and maintenance personnel stationed along the line routes through the intermediate carrier stations.

The hydel power is to be distributed from the HV step-down sub-stations for rural electrification, lift irrigation, cottage industries, heavy industries, etc by the low tension feeders to be put up by the Electricity Boards in the two States.

Under the first stage of development, Chambal hydel power will be made avilable in 1959-60 at the low tension bus bars of HV step-down sub-stations of Ujjain, Indore, Bhopal, Neemuch, Nagda, Ratlam, Mandsaur and Gwalior in Madhya Pradesh and Sawaimadhopur, Kota, Lakheri Jaipur, Ajmer and Udaipur in Rajasthan State.

The details of the transmission lines in the two States are given in tables 2 and 3.

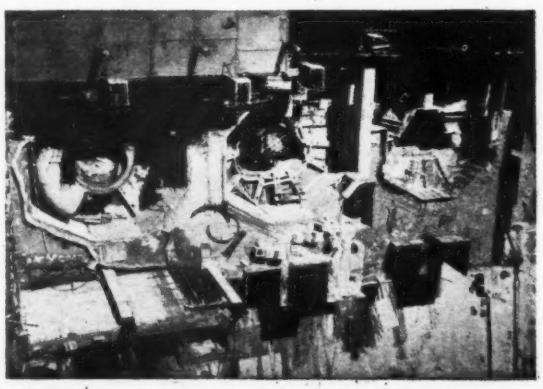
Table 2

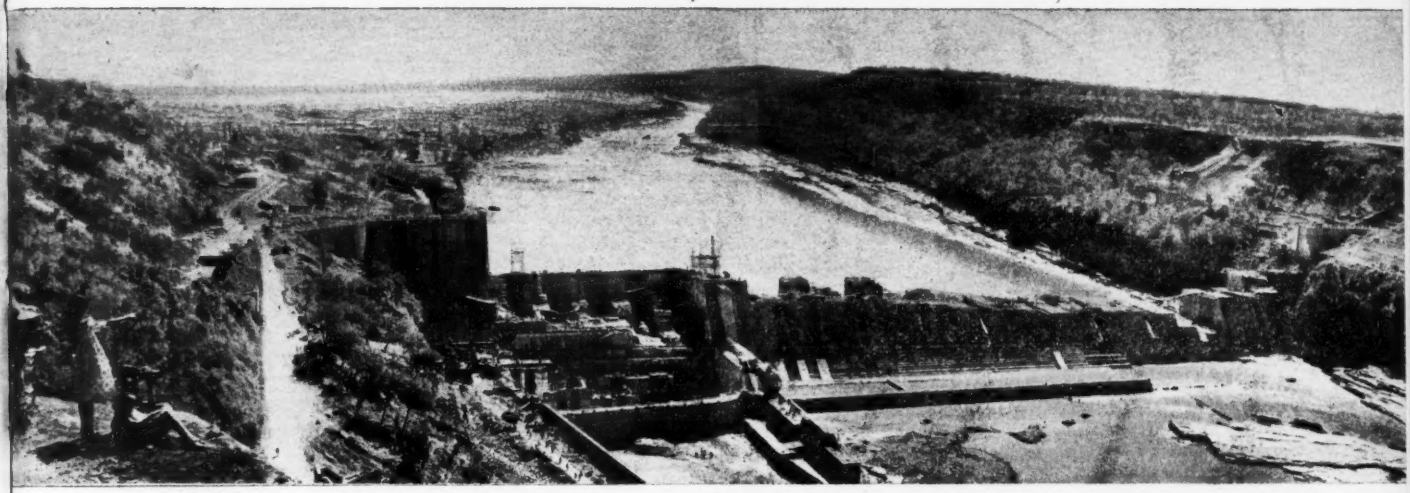
Sl. No.	*Transmission lines in Madhya Pradesh*	*Length in miles*	*Line voltage in kV*	*No. of circuits*	*Remarks*
1.	Gandhisagar Dam Ujjain	118	132	2	
2.	Ujjain-Bhopal	117	132	2	
3.	Gandhisagar Dam Neemuch	48	,,	1	
4.	Ujjain-Indore	32	66	2	
5.	Ujjain-Nagda	32	,,	1	
6.	Nagda-Ratlam	27	,,	1	
7.	Neemuch-Mandsaur	28	,,	1	
8.	Sawaimadhopur-Gwalior	125	132	1	S/c strung on D/c tower

Table 3

Sl. No.	*Transmission lines in Rajasthan*	*Length in miles*	*line voltage in kV*	*No. of circuit*	*Remarks*
1.	Gandhisagar-Kotah	43	132	2	
2.	Kotah-Lakheri	42	,,	2	
3.	Lakheri-Sawai-madhopur	32	,,	2	
4.	Sawaimadhopu-Jaipur	87	,,	1	
5.	Kotah-Ajmer	117	,,	1	
6.	Neemuch-Udaipur	81	,,	1	

A view of the construction in progress





A panoramic view of the Dam

Cheap hydel power from Chambal will promote the growth of the following new industries in the Chambal Project area in the two particapating States.

1. Gement factories at Chittorgarh and Neemuch
2. Rayon factory at Kotah
3. Sugar and power alchohol factories in Morena, Bhind and Ratlam districts.
4. Cotton mill at Nagda
5. Zinc smelters at Udaipur
6. Copper industry in Alwar district
7. Chemical industries in Nagda and Sambhar district
8. Feromanganese plant in Banswara district
9. Hard board factory at Nimar district
10. Insulator factory at Mandsaur

The Madhya Pradesh and Rajastahan Electricity Boards have formulated their power development programmes which will add considerably to the power resources of the region. This when pooled with the Power system of the Chambal Valley Development Scheme will form a vital link in All India Power Grid.

The work on the Gandhisagar dam and power house is in good progress. Out of a total of 256 lakhs cft of masonry involved in the construction of the dam, 168.62 lakhs cft. or about 66% have been completed. On the power house side, nearly 71% of the masonry work i.e. about 12.98 lakhs cft. out of 18.3 lakhs cft. is already completed. All the five penstocks have been installed and the erection of the first generating unit has been taken in hand.

Continued from page 111]

Development of High Pressure Thermal Power Station

in Calcutta will have to be weighed against generation at remote distance and transmission of the power to Calcutta. The more economical alternative has to be adopted to meet the power requirement.

Whatsoever might be the alternative adopted to meet the power requirement in this area, a thermal power station has to be set up, whether in Calcutta or outside, the basic design of which has to be in line with the present practices followed in the Continent and the U S. A. where the development of power stations had been almost on similar lines, but the former has been successful in achieving higher pressure and temperatures of live steam, earlier than the latter.

Development of High Pressure Thermal Power Station

By L. N. MISRA
Siemens Engineering & Manufacturing Co. of India Private Ltd., Calcutta

Before Independence we had been following mainly the practices prevailing in United Kindgom for the design and layout of Steam Power Stations.

The maximum pressure and temperature, commonly in use, were limited to about 450 psig (31. 64 kg/cm²) and 420°C (788°F). After Independence, specially during the 5 Year Plan, the trend in the design of modern power stations, has completely changed. It is mainly because of the following reasons, which are based upon the international practices, now being adopted:

1. Thermal power plant technique has considerably improved after the 2nd World War. Even super critical pressure boilers and turbosets have been successfully put into operation.

2. By experience it was realised that by increasing pressure of live steam and keeping the temperature constant better efficiency can be obtained though it follows the law of Diminishing Returns as shown in the enclosed diagram no. I, but better efficiency is obtained by increasing the temperature of live steam.

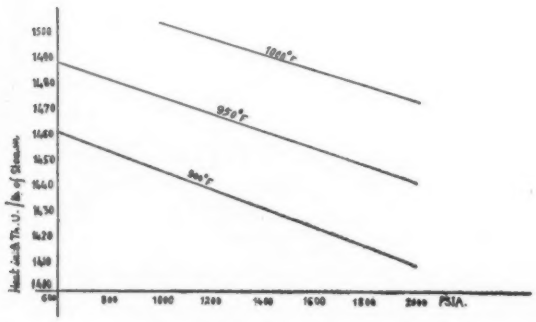


Fig. 1

3. Use of higher temperature necessitated adoption of alloy steel in the high temperature zone, specially superheaters in the boilers, live steam pipe lines and the high temperature stages of the steam turbine.

Researches carried out by Metallurgists in collaboration with steam turbine designers made it possible to exceed the temperature limit of 450-530-565-650°C (842-986-1049-1202°F). For temperature above 565°C (1049°F) austenitic steel is used. It is the costliest alloy steel available at present for the turbine industry. Ordinary chrome and Mo steels are cheaper than the Austenitic steel. Suitability of this steel for steam turbines enabled the designers to make turbines operating at temperature upto 650°C(1202°F). Raising of temperature of live steam at a constant pressure increase the available heat per lb. of steam almost in proportion to the rise of temperature of live steam as shown in the enclosed diagram no. II.

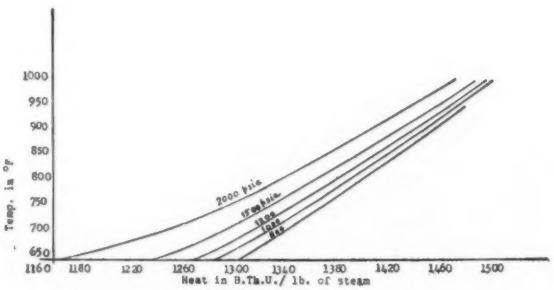


Fig. 2

4. By adoption of large single units the specific heat consumption per kWh goes down. This fact has been well-established and that is why single unit sets of even 500 MW are under construction and it is likely that in future even bigger sets will be put in operation.

5. Specific steam consumption/kWh has gone down if single or multiple stage reheating of steam is adopted, as is indicated by the enclosed diagram No. III.

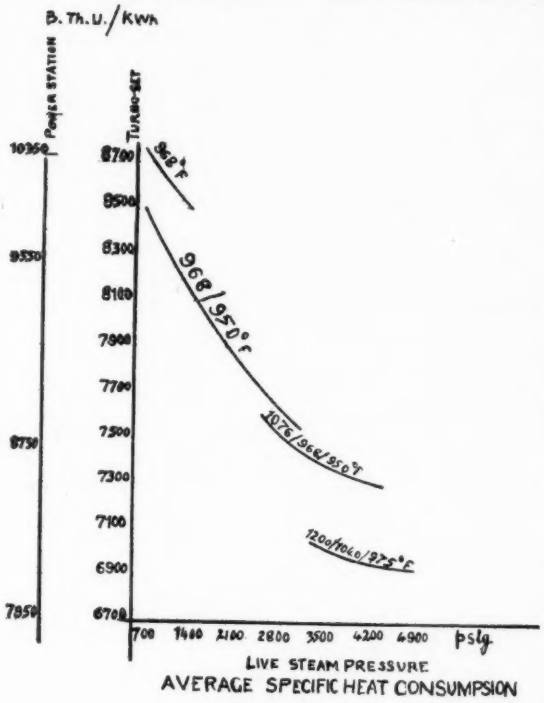


Fig. 3

6. It is realised that a unit type power station is easier to operate at a better efficiency. That is why big utility stations in the growing interconnected networks are designed as Unit Power Stations.

7. In unit system, tandem compounding of turbosets upto 125 MW and cross compounding from 100 MW & above is advantageous. Tandem compounded sets of 250 MW have already been commissioned and 350 MW are being designed—Figure 4.

8. Adoption of hydrogen cooling system for the generators above 50 MW is more efficient.

9. Maintaining of reheat temperature of steam at or very near to the live temperature as for example 960/960°F (515.5/51565°C) or 1050/1020°F (565./548.9°C). Reheating is used not only to bring down the specific heat consumption per kWh but to increase the capacity of the turbine also, because it relieves the low pressure stages. See fig. 5.

10. Raising the feed water temperature in various stages—say in 3 to 7 to 380°F (193.3°C) to 440°F (226.7°C) and above and lowering down the flue-gas temperature of the boilers to about 250°F (121.1°C) to 320°F (160°C) increases the efficiency.

11, In unit power stations with one boiler and one turbine the turbosets are usually arranged at right angles to the axes of the turbine house.

12. Depending upon location and cost of land adoption of horizontal low or vertical high designs for boilers are bringing down the capital investment and running expenses.

13. Joint thermal and electric control rooms located as near as possible to the centre of the operation of the plant have proved very advantageous beyond dispute. See figure 6.

The above facts have already been long established and are being widely adopted by designers of modern thermal powr stations in USA and the Continent. In U. K. a cross compound single unit of 550 MW is under construction. The cost of modern thermal power stations has been reduced by adopting better designs for boilers, turbines and switchgears. Switchgears and wiring cost approximately 15% of the total cost, whereas the turbosets and the connected equipment amount to about 30% of the total cost. Boilers cost approximately 30% and the building and foundations approximately 25%. Only in case of high cost of land the reduction in cost of building and the boilers was made possible by adopting the 'Tower' type boilers as shown in the diagram 17. This diagram indicates the development of 'Tower' type boilers. Figure *a* is a cross sectional view of a single flue boiler, the flue gas air preheater and induced-draught fan are arranged on the top. Figure *b* is also of single flue boiler, steam air preheater is arranged in the bottom and induced-draught fan is arranged at the top. Figure *c* is cross section of a single flue type of boiler with pressure furnace without induced draught fan. Figure *d* illustrates transverse flue boiler which has preheater and induced-draught fan at the top. This type of boiler will require a very little floor area and can be easily built up in a very congested area where the space is limited, at a considerably low cost. The fuel consumption and the reliability of service of such type of boilers are as good as any other boiler. The development of once-through forced circulation boilers has further reduced the operating as well as the initial cost of a boiler house. Supercritical pressure operation has become possible only due to this type of boiler. This boiler, above 1400 lbs/inch (98.4 kg-cm^2) pressure is cheaper than its counterpart—the Natural Circulation Boiler. The diagram no. 8 indicates the sectional views of the Benson Boilers.

Figures, 3 and 5 indicates the possible optimum of specific heat consumption in B.T.U. per nett kWh output under most favourable conditions. For comparison sake 3 tempeatures have been taken with and without reheat. The specific heat consumption decreases by adoption of the single reheat cycle and the efficiency gains thus obtainable still increase when double reheat is adopted as becomes evident from diagram no. 3. By adopting single or multiple reheat cycles cost of the installation goes up, but saving is effected in consumption of coal which economises coal and ash handling plants also.

The long established method of increasing the efficiency of the power stations is by adopting regenerative heat cycle. Mostly 3 to 7 extractions are taken from steam turbines to raise the feed water temperature, as shown in diagram no. 9.

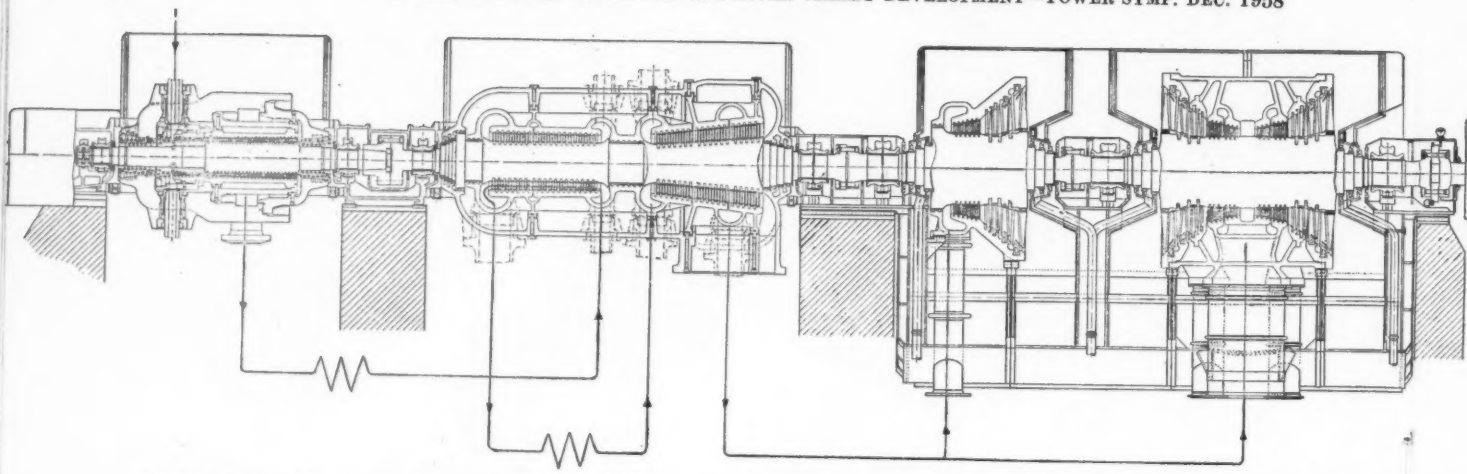


Fig. 4:—250000 kW condensing steam turbine 300/330 kg/cm² (4266/4977 lbs/sq. inch), 600/620°C (1112/1148°F) with double reheating at 560 (1040/1058°F).

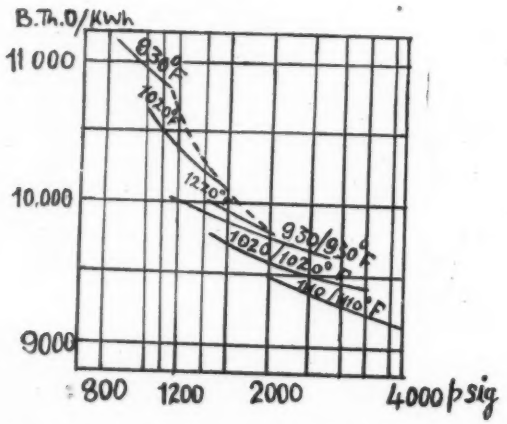
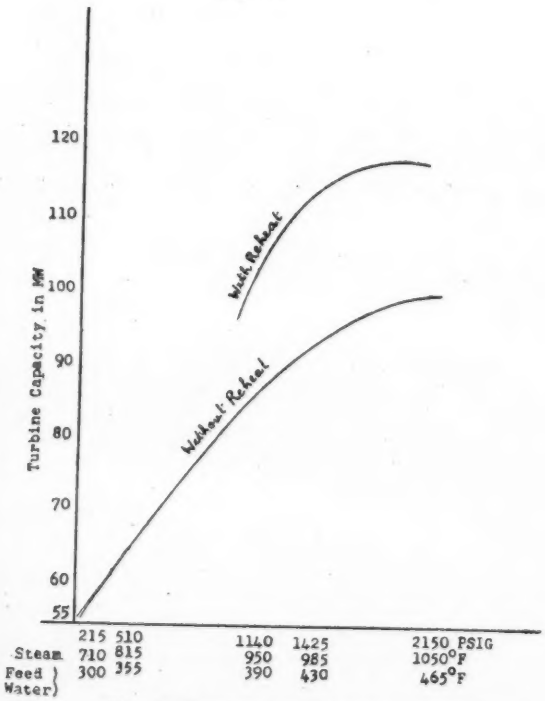


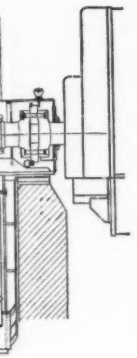
Fig. No. 5a :— Specific heat consumption at M. E. R.

Fig. No. 6 :—Joint Control and Thermal Room for Unit Power Station of 560 MW cap.

Fig. 5(b)



Rise in Turbo-set capacity with equal L.P. stages due to live/Reheat condition.



ing at 560/570°C

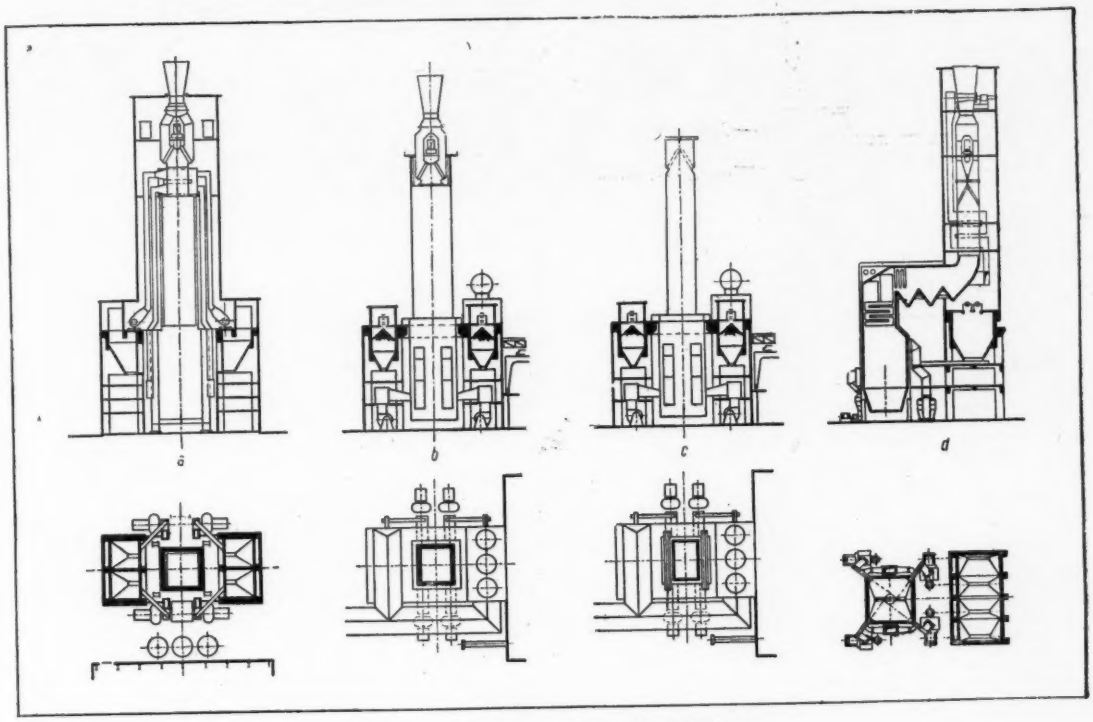
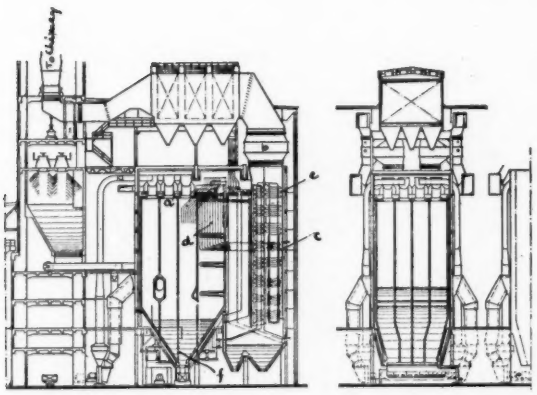


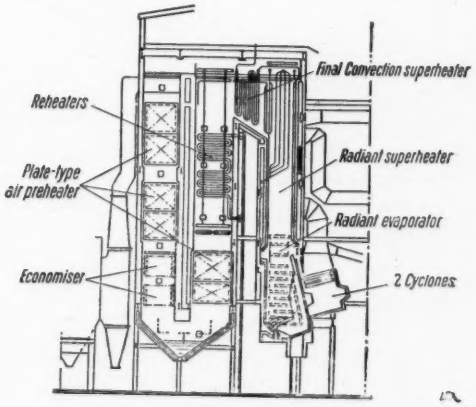
Fig. No. 7 :—'Tower' type Boilers.

Fig. No. 8 :—Benson Boiler.



(a)

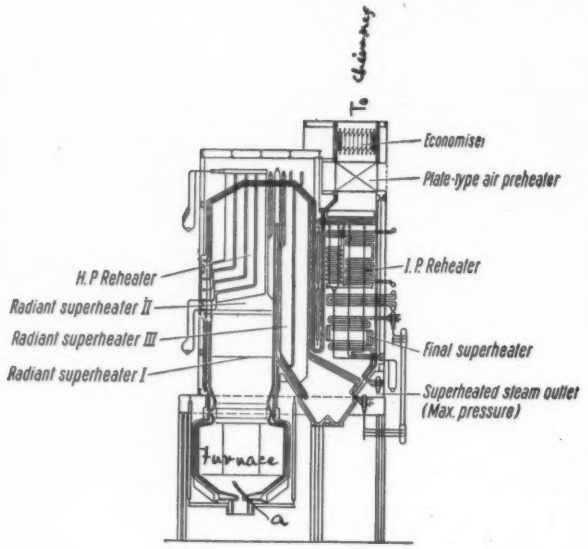
Capacity — 450 Tons/hr.
Steam Pressure — 2500 psig
Steam Temperature — 525°C
(a) Roof Burners
(b) Ljungstrom (Regenerative) Air Heaters
(c) Reheaters
(d) Superheaters
(e) Economiser
(f) Furnace



8 (b)

Capacity 185 tons/hr.
Steam Pressure 2800 psig.
Steam Temperature : 560°C.

Figure no. 10 deals with the characteristics of 300 MW power station having various sizes of turbosets. The lowest size is for alternative I of 50 MW and maximum size of 100 MW for alternative VI. In order to arrive at comparative figures alternative VI has been taken to be the reference point. It will be noted that the initial cost, heat consumption and generating cost per unit go on gradually increasing from alternative VI to alternative I. Plan and sectional views of the power stations are also shown. In the alternative I only 1 (one) chimney has been provided for 3 boilers, and the turbines have been arranged at right angles to



(c)

Capacity 250 tons/hr.
Steam Pressure 3500 psig.
Steam Temperature : 610°C
(a) Wet bottom furnace.

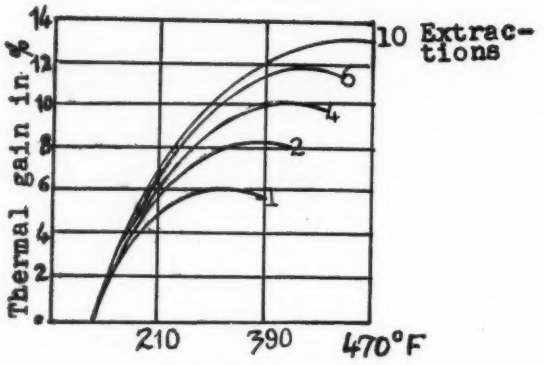


Fig. No. 9 :— Feed Water Temperature

the axes of the boiler which is the case in alternative IV and V also. In alternatives II, III and VI boilers and turbines are on parallel axes

In view of the above trend in the design of modern power stations we have also started adopting the American and the Continental practices which are basically similar. The Bokaro Thermal Power Station of DVC, which has got 2 boilers per turboset, is designed on unit system on the lines of the practices followed in U. S.A. on unit system. As yet we have not reached the stage to incorporate in our design for thermal power stations, the forced circulation once-through boilers and reheat cycles, which have already been successfully operated in U. S. A. and the Continent, specially Germany.

The present trend is to adopt single unit turbosets of as big a capacity as possible. For the DVC area, specially Calcutta and its suburbs, which has already been declared by CWPC as the mainly thermal area, endeavours by the designers should be made to adopt sets bigger than 75 MW with reheat cycle.

According to the load survey conducted by the CW PC the present demand of 288 MW will rise to 1015.7 MW in Calcutta area by 1976, whereas the firm power, available from the Calcutta Electric Supply Corporation, will go on decreasing to 252 MW by that time. The undernoted table will make the contention quite clear:—

Year	*CESC's area licensed*	*Supply under section 27 of 1910 I.E. Act*		*North Cal. grid inclusive of bulk supply to Gouripore*	*South Calcutta grid*	*Howrah Hooghly Scheme*	*Railway*	*Total*
		Bandel area	*Other*					
56-57	271	11	6	8.5	2	—	—	298.5
57-58	288	14	6	11	2	0.5	—	321.5
58-59	306	16	7	17.5	2.2	1.5	—	350.2
59-60	324	18	7	31	2.5	2	—	384.5
60-61	340	30	8	35.5	2.7	2.5	42.5	461.2
61-62	260	33	8	41	3	2.8	42.5	490.3
65-66	452	45	10	67	4	3.7	42.5	624.2
70-71	572	60	12	107	5.2	5.0	42.5	803.7
75-76	720	75	15	150	6.7	6.7	42.5	1015.7

The Government of West Bengal Thermal Power Station, which is under erection at Durgapur, is designed according to German practice. In the latter power station the steam pressure and temperature are higher than what it is at Bokaro, though basic features are similar. The DVC power station of 150 MW at Oaria is another landmark as the drum pressure in the boiler is 1720 psig (120.9 kg/cm^2) and each turboset is rated at 75 MW with live steam pressure of 1500 psig (105.5 kg/cm^2).

The above few examples clearly indicate that we are going in favour of high pressure and temperature power stations with one boiler and one turbine working

The nett difference of 763.7 MW will have to be met from other sources. The power to this area can be supplied either from the local power stations or from the DVC grid. In both the cases this power has to be got from coal, as the hydraulic potentiality is nominal and abundance of coal in this area exists with the necessary transport facilities. Considering the cost of atomic power stations and the fact that design and operational experiences regarding such plants are still in the early stage of initial development in other countries, it seems to be very remote that by the end of the Second Five Year Plan or even the 3rd, Atomic Power Stations willbe feasible in this area. Hence the primary source of energy will remain coal. As such thermal power stations

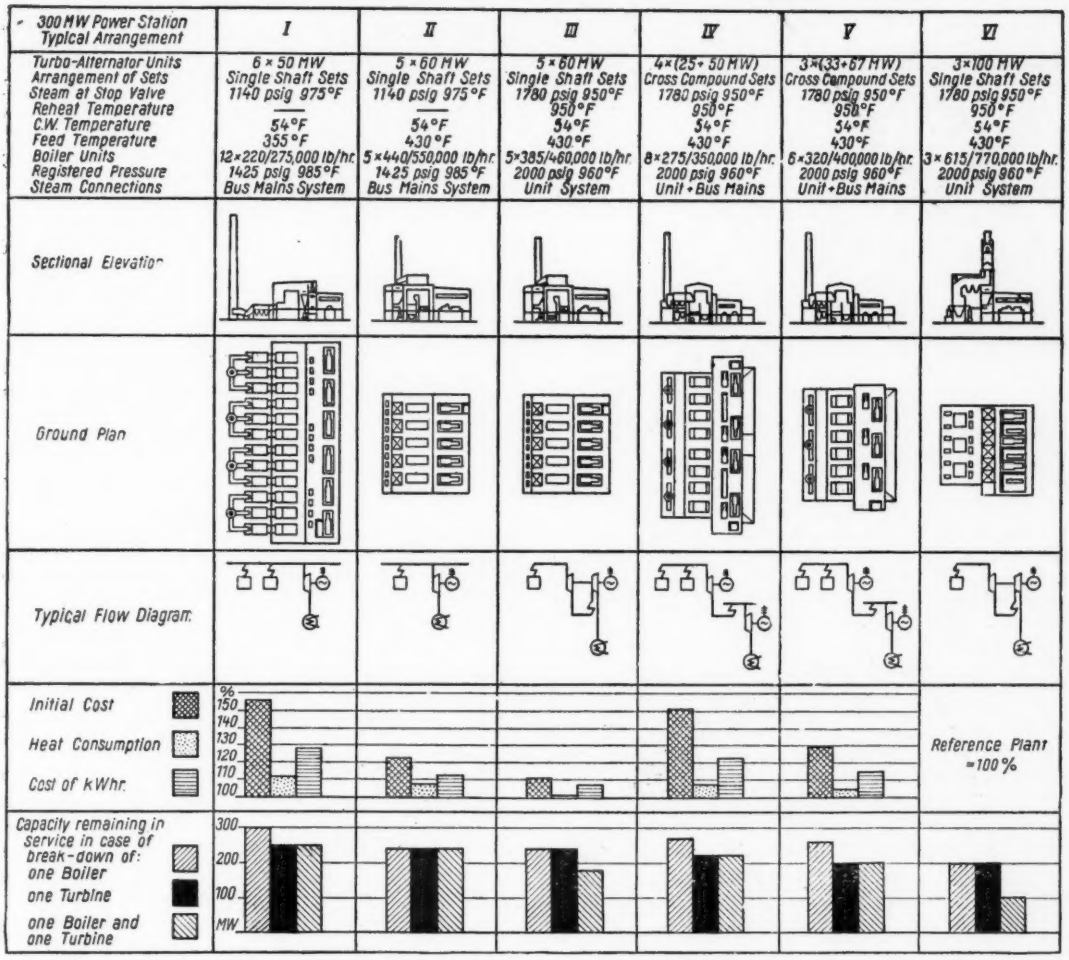

300 MW Power Station Typical Arrangement
I
II
III
IV
V
VI
Turbo-Alternator Units
Arrangement of Sets
Steam at Stop Valve
Reheat Temperature
C.W. Temperature
Feed Temperature
Boiler Units
Registered Pressure
Steam Connections
6 × 50 MW Single Shaft Sets 1140 psig 975°F — 54°F 355°F 12×220/275,000 lb/hr. 1425 psig 985°F Bus Mains System
5 × 60 MW Single Shaft Sets 1140 psig 975°F — 54°F 430°F 5×440/550,000 lb/hr. 1425 psig 985°F Bus Mains System
5 × 60 MW Single Shaft Sets 1780 psig 950°F 950°F 54°F 430°F 5×385/460,000 lb/hr. 2000 psig 960°F Unit System
4×(25+50 MW) Cross Compound Sets 1780 psig 950°F 950°F 54°F 430°F 8×275/350,000 lb/hr. 2000 psig 960°F Unit + Bus Mains
3×(33+67 MW) Cross Compound Sets 1780 psig 950°F 950°F 54°F 430°F 6×320/400,000 lb/hr. 2000 psig 960°F Unit + Bus Mains
3×100 MW Single Shaft Sets 1780 psig 950°F 950°F 54°F 430°F 3×615/770,000 lb/hr. 2000 psig 960°F Unit System
Sectional Elevation
Ground Plan
Typical Flow Diagram
Initial Cost
Heat Consumption
Cost of kWhr.
%
150
140
130
120
110
100
Reference Plant =100 %
Capacity remaining in service in case of break-down of:
one Boiler
one Turbine
one Boiler and one Turbine
300
200
100
MW

Fig. No. 10 :— Characteristic of different types of 300 MW Thermal Stations.

will have to be erected to meet the additional demand of load, either in Calcutta area or around it.

Due to certain legal obligations with Calcutta Electric Supply Corporation there exists very little chance of setting up a Power Station in Calcutta area itself. Should the contract with the Calcutta Electric Supply Corporation be revised and a superthermal power station set up in the area, it will be the best solution to meet the demand economically.

To start with, a 100 MW single unit tandem compounded power station should be built in Calcutta to be stepped up to 800 MW by 1976 in 4 stages. If this should not be possible, the other site for installation of this super-thermal power station would be just outside the licensed area of the Calcutta Electric Supply Corporation—say Bandel, which is approachable by road as well as the DVC navigation canal. This area has also been marked for indstrial improvement by the Government of West Bengal. The availability of cheap and sufficient power will help industrialisation very rapidly.

At present the Calcutta Electric Supply Corporation are receiving 40 MW power at Howrah from the DVC grid. This supply of power has to be continuously stepped up to meet the rising demand of the Calcutta Electric Supply Corporation. At present the power mainly from Bokaro Thermal Power Station of DVC. Completion of the Durgapur Power Stations will curtail the length of the transmission line to about 100 miles.

In planning to meet the requirements from Durgapur it is worthwhile to consider the economic capacity of the transmission system. Considering the limiting values of 132 kV and 220 kV Transmission Lines to be approximately 100 MVA and 300 MVA respectively, it would appear that 132 kV stystem may not be sufficient by 1960 and the 220 kV transmission by 1965. That is why the cost of generation of power

[*Continued on page* 105

Our Contributors

Mr. Hafiz Mohammad Ibrahim was educated in the Aligarh Muslim University and University of Allahabad. Practised as an Advocate at Nagina, Bijnor and Moradabad for over 21 years; inquired into the affairs of National Arabic University (Dar-ul-Ulum) Deoband; was elected member of the U. P. Legislative Council in 1926 and joined Swaraj Party. Since then continued to be Member of the U.P. Legislature till appointment as Minister, Irrigation and Power, India; worked for the organisation of Muslim Waqfs of U.P. opposed the White Paper proposal in 1934; was appointed Minister in the first Congress Cabinet of U. P. 1937; resigned from the Ministership in 1939 sentenced to one year 1940-41 for political work; detained in August 1942; has fought vehemently for Hindu Muslim unity and accord; was one of the main founders of Muslim Majlis in 1943 and later in 1947 convened All India Muslim Conference under the presidentship of Maulana Azad at Lucknow, which called upon the Muslims of the country to give up communal politics; appointed again as Minister of U. P. in 1946 and continued as such till 1958 and held charge of Finance, Power, Industries, Irrigation, Public Works, Forests and Co-operation Departments, appointed as Minister for Irrigation and Power, India, 1958 (April).

Is a Member of the A. I. C. C., Working Committee, Central Parliamentary Board and U.P. Congress Committee.

Dr. M. Datta was educated at the College of Science and Technology of Calcutta University from where he gained first class in Applied Physics in 1927. In 1933 he went for higher studies in the Municipal College of Technology, Manchester University and secured M. Sc. Tech. He joined M/s. Metropolitan Vickers Electrical Co. Ltd., and M/s. B.I. Cables before he was selected by the Govt. of India for commercial training in the Electric Supply Industry in England. On return he took charge of the Commercial Wing of the Electricity Development Directorate. In 1950 he was awarded the degree of Ph. D. by the University of Edinburgh and also became Member of the Institute of Electrical Engineers, London, in 1951. Since the formation of the West Bengal State Electricity Board, Dr. Datta held the office of the Secretary in addition to his own as Superintending Engineer till 1956 when he was sent abroad by the State Electricity Board for obtaining experience in Hydro Power Engineering. Dr. Datta is at present Chief Engineer of the State electricity Board, West Bengal. He has been elected the President of the Engineering and Metallurgical Section of the Indian Science Congress for the year 1959.

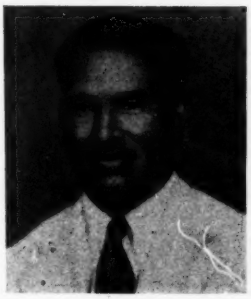
Mr. M. Hayath graduated in Engineering from the University of Mysore in 1923. He joined the Mysore Public Works Department in 1924. Deputed by the Government of Mysore for Foreign Training from 1927, to 1930 he obtained the B. S. E. E. degree from the Union University, Schenectady, New York. From 1941 to 1953 he was the Chief Electrical Engineer to the Government of Mysore. He served as Power Consultant to ECAFE at Bangkok for 14 months in 1951-52. After retiring from the Mysore service, he joined the ECAFE again in January 1953 as Chief of Power Division. He returned from Bangkok in 1954 and joined the Central Water & Power Commission as Member (Hydro Electric). He has taken over as Chairman of the Commission from 15th October 1958.

Dr. A. Lahiri was a brilliant student of the Presidency College, Calcutta and obtained Ph. D. in U. K. for his thesis which was also awarded the Judd Memorial Prize. He specialised in chemical engineering and fuel technology and conducted original researches on oil shales. After a brief period as a research assistant to Professor Egerton, F. R. S. he was in charge of the Fuels and Oil Laboratory of the Royal Aircraft Estabishment, England. On return to India in 1945 he was Assistant Director (Planning) of the F. R. I., becoming a Deputy Director in 1953 and Director in 1954. His research publications number nearly 200 and he shares considerably in the planning of fuel-based industries of India since independence.

Mr. S. S. Kumar graduated in 1922 from Government College, Lahore, Punjab University. He received his M. Sc. in Physics in 1924 standing 1st in the University. He graduated in 1927 from City & Guilds Civil Engineering (*A. C. G. I.*) and obtained Postgraduate Diploma in Hydro-Electric Engineering from Imperial College (*D. I. C.*) in 1928. He secured B. Sc. Hons (Engineering) London in 1927 and M. Sc. (Engineering), London in 1929.

After obtaining practical experience in the Shannon Hydro-Electric Scheme in Ireland, joined the Punjab P. W. D. Electricity Branch in 1934. Became Project Engineer there in 1944 by selection through Public Service Commission and was deputed to U. S. A. for 9 months in 1945 to gain experience in latest design and construction practices in Hydroelectric generation and transmission of power etc. On return planned and designed the Rasul Hydro Electric Project (now in West Pakistan) and the power portion of the Bhakra-Nangal multipurpose project. Promoted as Chief Engineer and Electricity Secretary to the Government, Punjab P. W. D. on first April 1948 and after completing the construction and commissioning of the Nangal Power Project came on deputation in May 1955 to the Central Water and Power Commission, Ministry of Irrigation and Power Government of India, as Member (Utilization). Let the Indian Delegation in 1956 on three months Group Study Tour of Electrical Engineering Experts of ECAFE Region to U. S. S. R., Sweden, U. K., France, West Germany, Czechoslovakia, U. S. A. and Japan.

Mr. A. K. Bhaumik is a Science Graduate from the Calcutta University in 1929 and B. Sc. in Engineering from the London University. Worked for about 2½ years with M/s. Metropolitan Vickers Ltd., London and on his return for about 2 years in the Railways, 3-4 years with M/s. British Insulated Callender's Cables Ltd., Calcutta, for construction and design of High Tension Transmission Lines and Substations. Five years Resident Engineer and Manager of a group of Electricity Undertakings in U. P. and subsequently another five years as Sr. Project Officer, Central Water and Power Commission, Govt. of India. His major work in the CW & PC has been assessment of load potentialities in various River Valley Project in India, such as Damodar Valley, Chambal, etc. Now for the last seven years he is Chief Electrical Engineer and Electrical Adviser to the Govt. of W. Bengal. Since 1955, also Electrical Engineer Member of the West Bengal State Electricity Board. A full member of the Institution of Electrical Engineers, London, and the Institution of Engineers, India



Mr. V. P. Appadurai joined Madras Electricity Department during 1932. He rose to the position of Superintending Engineer of the Technical Branch in 1948 and became Chief Engineer of the Madras Electricity Department in 1954. After the formation of the State Electricity Board in 1957, he is now the Chief Engineer and Technical Member of the Board.

During 1952 he visited U. S. A., Canada, U. K., and the Continent under the Colombo-Plan Fellowship Award.

During 1956 he went to Canada as a Member of the Govt. of India Delegation to finalise the terms of Colombo Plan Aid for the Kundah Hydro Electric Scheme. He again went to Canada during 1955 for finalising the orders for plant and machinery required for the Kundah Project and to Germany during 1958 to expedite the despatch of the generating machinery requird for the Periyar Scheme.

Mr. J. D'Sa Passed out from the College of Engineering in Bangalore in 1929. In 1930 he joined the University of Birmingham for electrical honours degree. After completion he joined as hydraulic operator at Sivasamudram in December, 1954. He was in charge of erection of two generating units at Shimshapura as wellas of the low pressure penstock pipes and surge tanks. He led a team of engineers to England in connection with the testing of equipment for Mahatma Gandhi Electric Works. On return after 11 years he was at the Jog Falls, rising to the position of General Superintendent and was actively engaged in the installation of 11 units installation of 120 MW. In 1955 he was posted as a General Superintendent of the Sharavati Valley Project. At present he is Chief Engineer Electricity, of the Mysore State.

Mr. G. C. Goswami went for engineering education to Bombay in 1929 and later to U. K. where he obtained B. Eng. in 1932 from the University of Sheffield. Joined as Assistant Engineer in A. O. C. Ltd. Digboi 1934 and then joined Gov. of Assam in the Electricity and Factory Inspectorate (1936). He went to Canada as a member of the Hydro-Electric Mission in 1951 when he was working as electrical Adviser (Development) under the State Govt. Since 1955, he has been working as Chief Electrical Engineer and Electrical Adviser to the Govt. of Assam and is now the Technical Member of the Assam State Electricty Board.

Mr Pierre L Misson, is the Engineer Director of Ets. Neyrpic who are leading manufacturers in the field of hydraulic equipment. Mr. Misson was the founder of Neyrpic organisation in North Africa. He has been associated with Hydro Electric Developments all over the world. In particular he had the occasion to work upon the development of Axial Flow machines dealt in this article.

Professor H. N. Ramachandra Rao received general education in Mysore and Calcutta Universities and electrical engineering education at the Indian Institute of Science. After six years service in industry, joined the academic line in 1942 and now working as Professor of Electrical Engineering at the Indian Institute of Science. His main interests are in Power System Engineering.

Mr. M. K. R. Menon is at present Superintending Engineer (Projects) M. P. Electricity Board. Mr. Menon after graduating from Engineering College, Banaras Hindu University in 1938, worked with the B. A. Rly and Central Water & Power Commission up to 1947. Since then he has been working in M. P. Electricity Board in various capacities and has been associated with the design, construction, operation and maintenance of Transmission and Distribution Schemes. Recently he has been on a study tour of U. S. A. for a period of 6 months visiting various Public Utilities.

Mr. S. Swayambu took the B. Sc. degree of the Madras University in 1931 and then a course in Electrical Technology in the Indian Institute of Science. Has served the Government of Madras for about 6 years and has been in the service of the Central Government in the Central Electricity Commission and later in the Central Water & Power Commission. At the present time holding the post of Director (Research). Had an opportunity to receive special training in hydroelectric practice in Canada in 1945-46, and again in the U.S.A. in 1957. Had also travelled extensively in the Continent as well as in Japan.

Mr. V. Venugopalan took his B. A. (Hons.) Degree of the Madras University in 1929 and obtained the Certificate of Proficiency in Electrical Technology from the Indian Institute of Science, Bangalore, in 1933. He joined the Madras Govt. Electricity Department in 1934 and worked in various capacities till 1947, when he joined the Government of India as Project Officer in the late Central Technical Power Board. He is now Director (Transmission) in the Central Water & Power Commission (Power Wing).

Mr. K. S. Sivaprakasam is Superintending Engineer (Electrical) in the Chambal Hydel and Irrigation Scheme, Madhya Pradesh. His services have been lent by the Mysore Government to the Madhya Pradesh Government fo. this project.

Mr. G. R. Hukmani is head of the Technical Division of Kamani Engineering Corporation, Ltd., and controls Designs & Estimates, Testing & Research and Quality Control Departments. Messrs. Kamani Engineering Corporation Ltd. are a leading tower manufacturing industry who started transmission line tower manufacturing in 1950 with the technical know-how from a French Industry. However, since 1954 the industry is run entirely by Indian personnel.

Mr. Indru T. Advani is an Engineer working on the design of Hydraulic Projects with Ets. Neyrpic since the last 5½ years. He has had the occasion to be associated with Hydraulic Projects in India and he has been devoting some time lately on the development of Axial Flow Units.

Mr. A. Ghosal was educated at the Science College, Patna, where he took a first class honours degree in mathematics, and Calcutta University where he obtained an M. Sc. degree in Statistics in 1948. Later, he became an Associate of the Institute of Actuaries, London, through a series of examinations. From 1949 to 1953 he was a Statistician with the Eastern Railways at Calcutta. He joined the Central Fuel Research Institute as Junior Scientific Officer(Statistics) in mid-1953. He was promoted to Statistical Officer early in 1958. In this Institute, he has been concerned mainly with the application of statistical methods in fuel problems and has been assisting research workers in preparing approporiate designs of experiments. He has conducted a series of theoretical and experminental investigations into coal sampling, on which he has contributed some papers. He is a member of the Coal Sampling Sub-Committee of the Indian Standards Institution. He has also published some papers on mathematical and applied statistics.

Mr. A. Shankaran is Director of "Load Survey and Load Development Directorate" in the Central Water & Power Commission. After graduating in Electrical Engineering from the Bombay University in 1939, Mr. Shankaran began his career as an Asst. Electrical Engineer in the Sholaput Mills. In 1943 he joined as an Asst. Director in the Directorate General (Supply), New Delhi, from where was transferred tothe Electrical Commissioner's Office Calcutta (now the C. W. & P. C. Power Wing) in 1945. In 1949 he went over to the Hirakud Dam Project then in its inception, remaining with that organisation until the middle of 1958, during which period he served initially as an Asst. Executive Engineer and later as Executive Engineer, being associated with almost all phases of construction on the electrical side of the Project including the 132/66 kV Transmission Lines and the Hydro Power House of the Hirakud Power System. His services were placed back at the disposal of the C. W. & P. C. in August, 1958.

Mr.B. N. Narayana Iyengar received general education in Mysore University and electrical engineering education at the Indian Institute of Science. After six years of service with the Kolar Gold Mining Companies, joined the Institute staff in 1944. Now working as Assistant Professor of Electrical Engineering at the Indian Institute of Science.

Mr. L. N. Misra passed combined Electrical and Mechanical Engineering Examinations of the Benaras Hindu University in 1950. He worked as Shift charge Engineer and Maintenance Engineer for 4 years in a Power Station of 15,300 kW till 1954. Underwent training as a Govt. of India Scholar in West Germany till May 1956. At present working as Steam Power Station Engineer with Messrs. Siemens Engineering & Manufacturing Co., of India, looking after the design and execution of Thermal Power Stations.

Sardar Harbans Singh graduated from the Agra University and then joined the Indian Institute of Science. After receiving his C. I. I. Sc., carried out research on Motors and Switchgear. From 1942 to 1945 worked in American Aerodrome Agra and Indian National Airways. Then Joined Punjab Government service in the Electricity Department and was promoted as Sales Engineer in September, 1953 and is at present holding this post. He is responsible for the sale of power both from the Uhl River Scheme and the Bhakra Nangal Power Project and for framing tariffs, commercial policies, conditions of supply etc. applicable to the supply of power from these projects, and for load forecast. He is also responsible for the framing and execution of special agreements for supply to the States of Delhi, Himachal Pradesh, and Jammu & Kashmir, the electrical portion of the partnership agreement of the Bhakra Nangal Project.

INDEX TO ADVERTISERS

Aluminium Industries Ltd.	facing page 7	Kirloskar Brothers Ltd.	Page iv
ABRED (Columeta), Luxemburg	page xxiii	Kirloskar Oil Engines Ltd.	,, xvi
Associated Electrical Industries (I) Private Ltd.	Third cover	Magrini, S.p.A., Italy	,, xiii
Batliboi & Co.	page 28	Martin Burn Ltd.	pages xii, xvii & 74
Bharat Bijlee Ltd.	facing page 23	National Electrical Industries Ltd.	page xxiv
Burmah-Shell Oil Storage & Dist. Co. of India Ltd.	page ii	National Insulated Cable Co. of India Ltd.	facing page 6
Cement Marketing Co. Ltd. (A.C.C.)	,, xiv	Nydqvist Holm Aktiebolag, Sweden	,, ,, 6
Charmilles Engineering Co. Ltd., Switzerland	,, xxv	Parry & Co. Ltd. (Motors)	page vi
Crompton Engineering Co. (Madras) Private Ltd.	,, xxi	Parry & Co. Ltd. (Transformers)	,, xx
Cementation Co. Ltd.	facing page 22	Parsons C. A., & Co. Ltd.,	,, xvii
Dominion Engineering Co. Ltd., Canada	page vii	Reyrolle A. & Co. Ltd.,	,,62
Dunlop Rubber Co. (India) Ltd.	,, viii	S. A. E. (India) Private Ltd.	Second Cover
Electrical Machines Corpn. Private Ltd.	facing page 59	Siemens Engineering & Mfg. Co. of India Pte. Ltd.	page i
English Electric Co. Ltd.	page 4	Stewarts & Lloyds of India Pte. Ltd.	,, xxii
Ets. Merlin & Gerin, France	,, ix	Structural Waterproofing Co. Pte. Ltd.	,, xxiv
Ferguson Pailin Ltd., England	,, xi	Scarpa & Magnano, Italy	,, iv
Goodyear Tyre & Rubber Co. of India Ltd.	facing page 58	Textile Machinery Corpn. Ltd.	,, xix
Greaves Cotton & Co. Ltd.	page xxviii	Timken made in U.S.A.	,, v
Greaves Cotton & Crompton Parkinson Pte. Ltd.	,, xviii	Voith, J. M., Austria	,, iii
Indian Cable Co. Ltd.	,, x	Voltas Ltd. (Brown Boveri)	Fourth Cover
Indian Hume Pipe Co. Ltd.	,, 73	Vulcan Trading Co. Private Ltd.	page xviii
Indian Iron & Steel Co. Ltd.	,, xii	William Jacks & Co. Ltd.	,, xv
Kamani Engineering Corpn. Ltd.	,, xxvi		

SPECIAL ISSUE

OF

INDIAN MINING JOURNAL

ON

"COAL CARBONISATION"

Date of publication : March 1959

Price : Rs. 20 per copy

Pre-publication Price Rs. 15

Book your orders with :

The Manager,

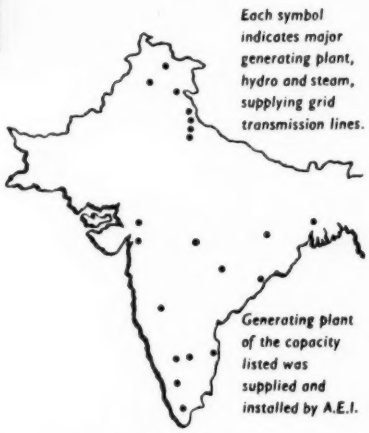
INDIAN MINING JOURNAL

6-2, Madan Street, Calcutta 13.

Printed and published by P. K. Menon from Inland Printing Works, 60/3 Dharamtala Street, Calcutta-13
Editorial & Managerial Office : 6-2 Madan Street, Calcutta-13

Power for the Millions by AEI

● Khaperkheda	30,000 KW
● Ramgundam	37,500 KW
● Ahmedabad	1,35,000 KW
● Surat	15,000 KW
● Visakhapatnam	6,750 KW
● Tatanagar	55,000 KW
● Kashmir	6,000 KW
● Jogindarnagar	48,000 KW
● Greater Calcutta	1,61,000 KW
● Madras (Basin Bridge) ● Pykara, Mettur, ● Papanasam and Moyar	2,15,450 KW
● Mysore (Jog)	48,000 KW
● Travancore	22,500 KW
● U. P. (Harduaganj) ● Bahadrabad, Bhola, ● Sumera & Muhammadpur	40,600 KW



Each symbol indicates major generating plant, hydro and steam, supplying grid transmission lines.

Generating plant of the capacity listed was supplied and installed by A.E.I.

Bhakra Dam Power Plant No. I

A. E. I. are proud to announce that they have been entrusted with the supply of five 100,000 KVA, 166.7 RPM, 11 KV, 50 CPS, 0.9 PF A. C. Generators. When installed these generators will be the largest in India.

ASSOCIATED ELECTRICAL INDUSTRIES (INDIA) PRIVATE LTD.

Head Office: Crown House, 6 Mission Row, Calcutta

Branches at:

BOMBAY NEW DELHI MADRAS BANGALORE COIMBATORE NAGPUR

AEI

ASSOCIATED COMPANIES

ASSOCIATED ELECTRICAL INDUSTRIES MFG. CO. PRIVATE L'
A.E.I.-HOTPOINT LTD.
A.E I. LAMP & LIGHTING CO. LTD.
BIRLEC LTD.
THE BRITISH THOMSON-HOUSTON CO. LTD.
FERGUSON PAILIN LTD.
INTERNATIONAL ALUMINIUM CO. LTD.
METROPOLITAN-VICKERS ELECTRICAL CO. LTD.
METROPOLITAN-VICKERS GRS. LTD.
NEWTON VICTOR LTD.
SIEMENS EDISON SWAN LTD.
SUNVIC CONTROLS LTD.

AIC-154B

A.E.I.'S 'LIGHT' PRODUCTS – MAZDA LAMPS

Regd. No. C 3873

BROWN BOVERI

Electrical Equipment

— for industrial and power projects

BROWN BOVERI electrical equipment incorporates the latest advances in design and manufacture—to ensure top efficiency, safety, economy, ease of maintenance, and rugged reliability. Today, BROWN BOVERI Products are giving smooth, trouble-free service, often under the severest conditions, all over the world.

POWER GENERATION

Steam and Gas Turbines, Boiler-House Auxiliaries, Velox Boilers, Generators, Conversion Protecting and Regulating Equipment, Complete Steam Power Stations and Gas Turbine Installations

Hydro-Electric Power-plant, Emergency Sets, Switchgear for power stations of all types

POWER DISTRIBUTION

High-Voltage Switchgear, High and Low-Voltage Metal-Clad Draw-out Switchgear, Substations, Switch Desks and Switchboards

Rotary Converters, Static Converters, Charging Equipment for Batteries, Electrical System Protection Equipment

Transformers, Synchronous Capacitors and Phase Advancers

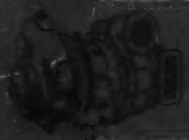
POWER UTILISATION

Complete Electrical Equipment for Industrial Plants, Variable Speed Drives, Motors of all sizes and types, High and Low-Voltage Industrial Switchgear

Electric Furnaces and Kilns, Radio-Frequency Generators for Industrial Applications, High and Low-Voltage Electric Boilers

Electric Welding and Arc Welding, Resistance Welding Installations

TURBO-COMPRESSORS AND BLOWERS

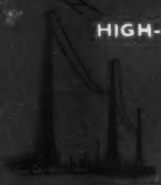


Turbo-Compressors, Blowers — Heat pumps, Exhaust-Gas Turbochargers

TRANSPORTATION

Traction

HIGH-FREQUENCY COMMUNICATIONS



Transmitting and Rectifier Tubes, Radio Sets, Radio-Relay Equipment, Transmitters, Carrier Equipment, Centralised Remote Control Equipment, Thyratron Units

ELECTROCHEMISTRY

Galvanizing Plants, Mutators and Converters, Contact Converters

Various other products

Betatrons, Gear Couplings and Laboratory Equipment

For full information, please write to:

VOLTAS VOLTAS LIMITED

BOMBAY · CALCUTTA · MADRAS · BANGALORE · NEW DELHI · COCHIN · LUCKNOW